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WEEKLY 3 September 2022

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The science of the Renaissance, Italy

Encounter the great scientific minds and discoveries of the Renaissance on a journey through the period's preeminent cities of science: Florence, Pisa and Bologna. Led by architecture expert Andrew Spira, you will discover the astronomical, anatomical and architectural collections, buildings and churches that demonstrate the knowledge of the period. This eight-day tour starts on 6 November and costs £1845.

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Podcast

Weekly

The team discuss a promising new trial that has used a fat molecule called butyrate to treat peanut allergies in mice. They also look at how we may be able to predict earthquakes using machine learning. Plus, philosopher and author Will MacAskill tells us about the concept of longtermism, which is about prioritising the long-term future of both people and planet.

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Italian wonders Embark on an adventure through the Renaissance

STOCKFOOD/NORTON, JIM

Nuts cracked A new treatment for peanut allergies works in mice

Video

Final countdown

NASA's Space Launch System (SLS) was due to take off on 29 August, but the launch was called off at the last minute. As *New Scientist* went to press, NASA was gearing up for a second attempt. The most powerful rocket ever built, SLS will take its capsule, called Orion, to an altitude of 4000 kilometres before falling back to Earth.

youtube.com/newscientist

Newsletter

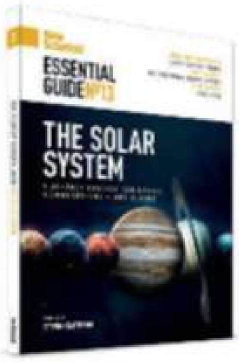
Launchpad

You might remember the Great Dimming of Betelgeuse back in 2019, in which a red supergiant star became fainter, so much so that the dimming was visible to the naked eye. Reporter Leah Crane talks to researchers who are analysing observations from a slew of telescopes and unravelling what happened.

newscientist.com/launchpad

Newsletter

"When you take out a big piece of a star's surface, what's left all sloshes around like an unbalanced washing machine"



Essential guide

How does the sun work? Why does the moon matter? Is there alien life? Knowledge of our solar system has reached new heights – but there is still much to discover about our nearest planets and the worlds beyond. Explore more in the latest *New Scientist Essential Guide*.

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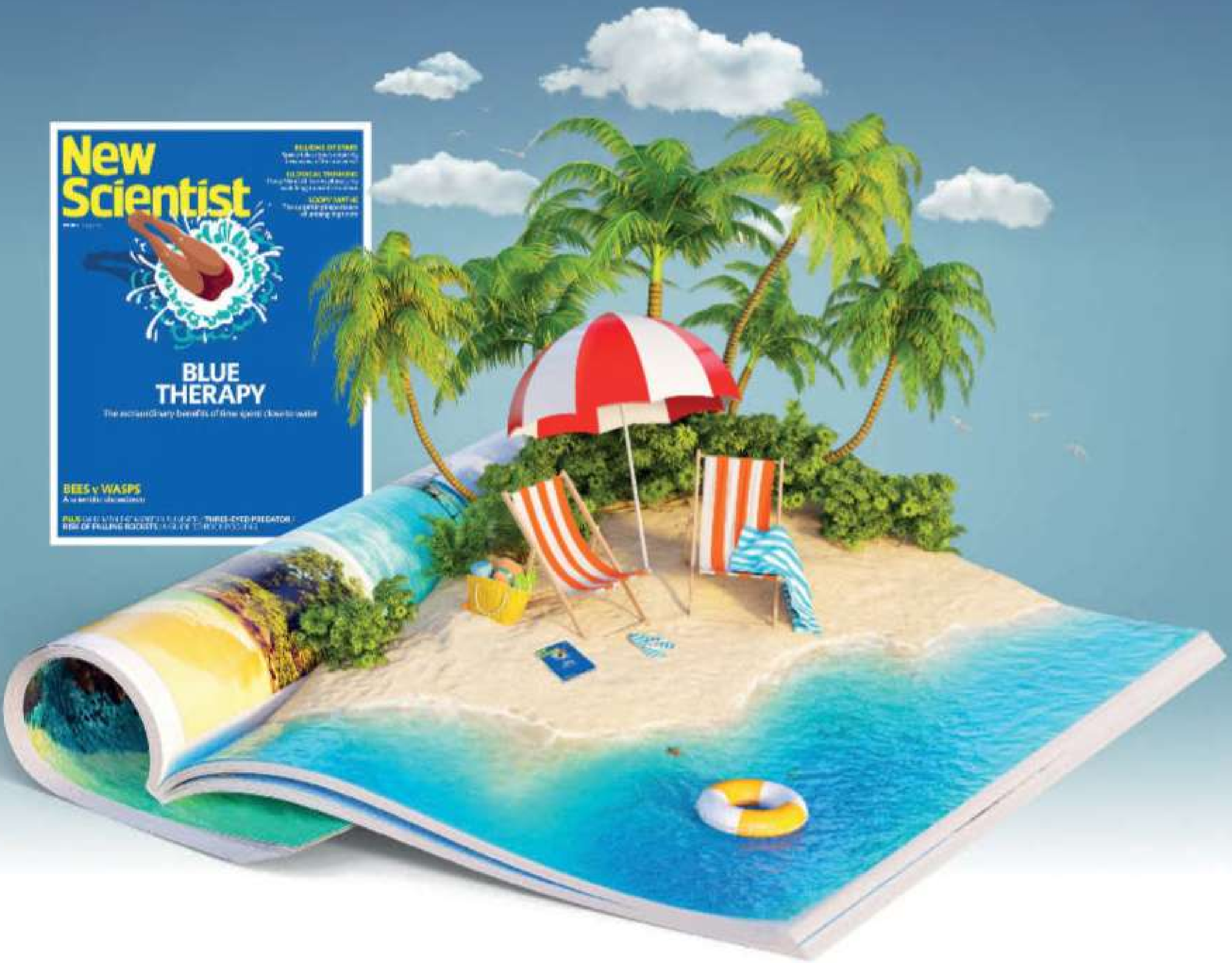

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Barrier to change

Outdated research on therapies for menopause symptoms is letting us down

NOT so long ago, the menopause was something to be discussed in hushed tones well out of the earshot of those who weren't going through it. Not anymore. We are in the midst of a revolution, with people demanding that science and society take a fresh look at a life event that can be so unpleasant that as many as 1 in 10 of those experiencing symptoms quit their jobs.

The message seems to be getting through, at least in some countries. The UK is blazing the trail, with the inaugural meeting of the UK Menopause Taskforce taking place earlier this year. It brings together politicians and clinicians to increase access to treatments for the symptoms of menopause and to tackle societal taboos. Meanwhile, a growing number of employers are implementing HR policies aimed at providing menopausal support in the workplace.

Like all revolutions, there is resistance. Arguments rage about the rights and wrongs of medicalising part of the ageing process. And the shadow of decades-old studies that questioned the safety of hormone replacement therapy (HRT) still looms over decisions on whether to use it to treat menopausal symptoms or to ride them out.

> "Let's be clear about the evidence around HRT and let people make up their own minds"

Where do we go from here? A much-needed first step is to make sure that doctors are up to speed with the real risks – and benefits – of HRT. It is wrong that people are still being refused treatment on the basis of outdated evidence, or being misdiagnosed with depression and anxiety because their doctors aren't aware of the toll menopause can take on mental health.

The prevailing message from the latest research is that, while HRT does carry some increased health risks, those are relatively small (see page 38). It is time to be clear about that, and let people make up their own minds.

As for further research, we need to refine the sledgehammer approach to treatment – and there are plenty of avenues ripe for investigation. The future should be about smarter options for HRT, not whether we use it at all. ▮

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News

Useful slime
Mucus has evolved at least 15 times in mammals **p9**

Addiction treatment
Psilocybin may help people stop drinking alcohol **p14**

Two-legged dinosaur
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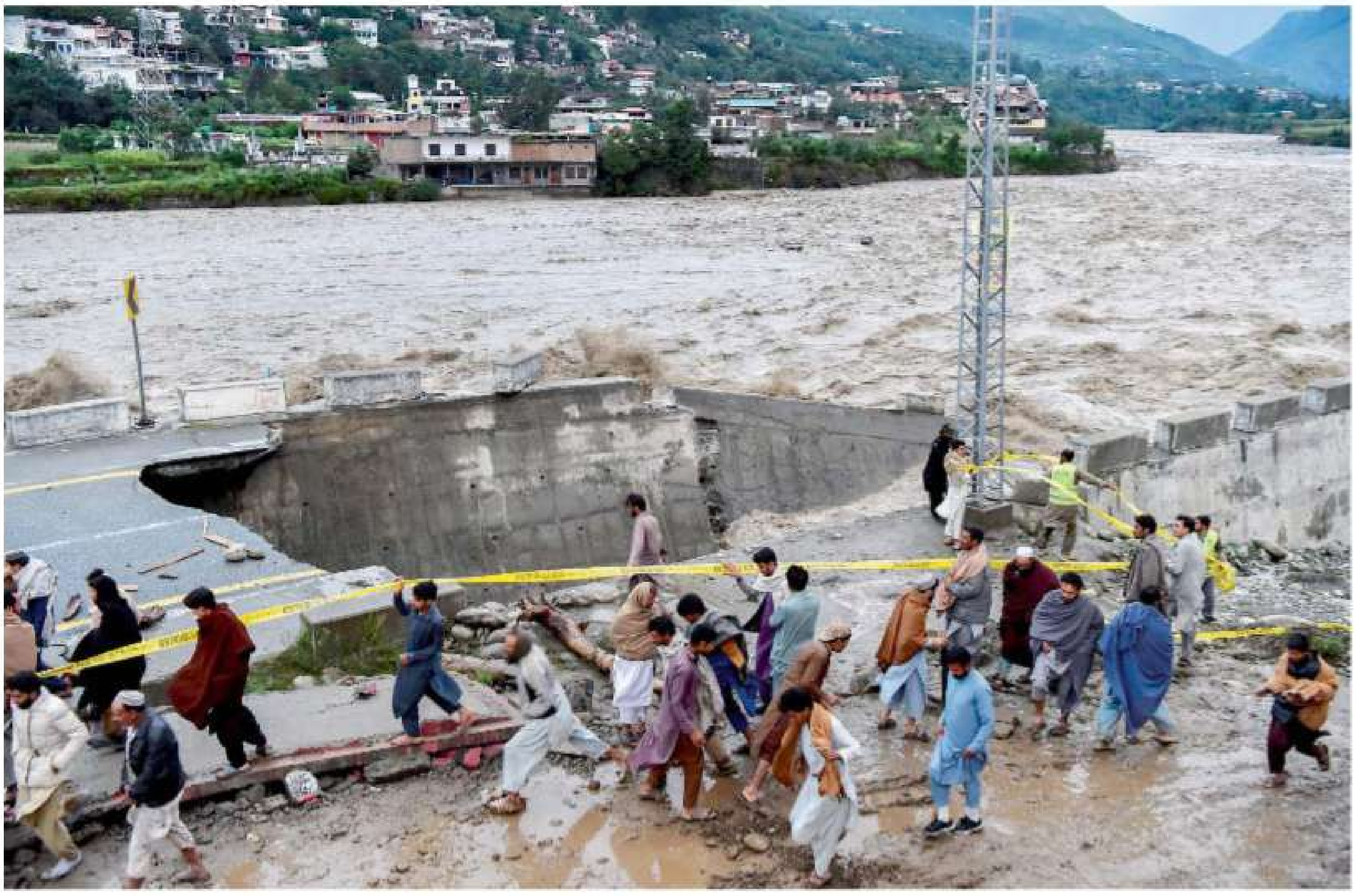
Superstrong lasers
Plasma could be used to make more powerful beams **p16**

Jupiter's glow
James Webb Space Telescope captures stunning photo **p21**



ABDUL MAJEED/AFP VIA GETTY IMAGES

A road damaged by flood waters in Madyan, Pakistan

Extreme weather

Deadly floods in Pakistan

Eight weeks of heavy monsoon rains have left a third of the country underwater and more than 1000 dead, reports **Adam Vaughan**

DEVASTATING floods that have killed more than 1000 people in Pakistan are a "climate catastrophe" requiring a strong international response, according to the secretary general of the United Nations, António Guterres.

"Pakistan is awash in suffering," said Guterres in a video statement on 30 August. "The Pakistani people are facing a monsoon on steroids – the relentless impact of epochal levels of rain and flooding." The UN has launched an appeal to raise funds to support those affected.

Eight weeks of torrential rain during a severe monsoon season have left a third of Pakistan underwater in the country's worst flooding since 2010. In some areas, unprecedented water flows have been estimated by the Global Flood Awareness System, a European satellite monitoring scheme, with the most extreme destruction taking place in the south of the country.

Bed frames and helicopters have been used to rescue people during the floods, which have affected more than 33 million people. Government ministers have claimed the disaster will have an economic cost of more than $10 billion.

Pakistan's climate minister, Sherry Rehman, said on Twitter on 29 August that one small town, Padidan, had received more than 1700 millimetres of rain in one day. In an interview with Sky News, she said rescue helicopters were having trouble finding dry land in the south. Rehman called the event a "huge humanitarian disaster" and "quite apocalyptic".

Pakistan has long been considered one of the most vulnerable countries in the world to the impacts of climate change, due to its geography and levels of poverty there. Earlier this year, the country, along with India, was hit by a prolonged and brutal heatwave. Jacobabad, one of the world's hottest cities, reached a record high of 51°C. A study has since found that climate change made the heatwave at least 30 times more likely.

> "The Pakistani people are facing a monsoon on steroids and epochal levels of rain and flooding"

In his address, Guterres said it was outrageous that action to reduce greenhouse gas emissions was being put on the back burner. "Let's stop sleepwalking towards the destruction of our planet by climate change. Today, it's Pakistan. Tomorrow, it could be your country," he said.

Rehman told the AFP news agency on 29 August it was time for big emitters – a reference to countries including China, the US, India and members of the European Union – to review their climate policies. The human and economic cost of the Pakistan floods is likely to provide fresh impetus at UN climate talks on the issue of "loss and damage", with lower-income countries calling for some form of reparations from large historical emitters for the impacts of climate change.

The subject is on the provisional agenda of the high-profile COP27 climate summit in Egypt this November, but it may yet get struck off. So far, richer nations have only agreed to further formal discussions on loss and damage.

The high number of deaths during the Pakistan floods suggests early warning systems are still failing to reach enough people, according to Liz Stephens at the University of Reading, UK. "Questions need to be asked about why these floods are having a similar impact to those in 2010, when nearly 2000 people died," she said in a statement.

While Pakistan is experiencing deadly floods, neighbouring China has been affected in recent weeks by a severe drought that has disrupted energy supplies and forced factories to close. ▮

Biology

Synthetic mouse embryos with rudimentary brain grown in the lab

Clare Wilson

SYNTHETIC embryos made from mouse stem cells have been coaxed into developing the beginnings of a brain and a beating heart while grown in the laboratory.

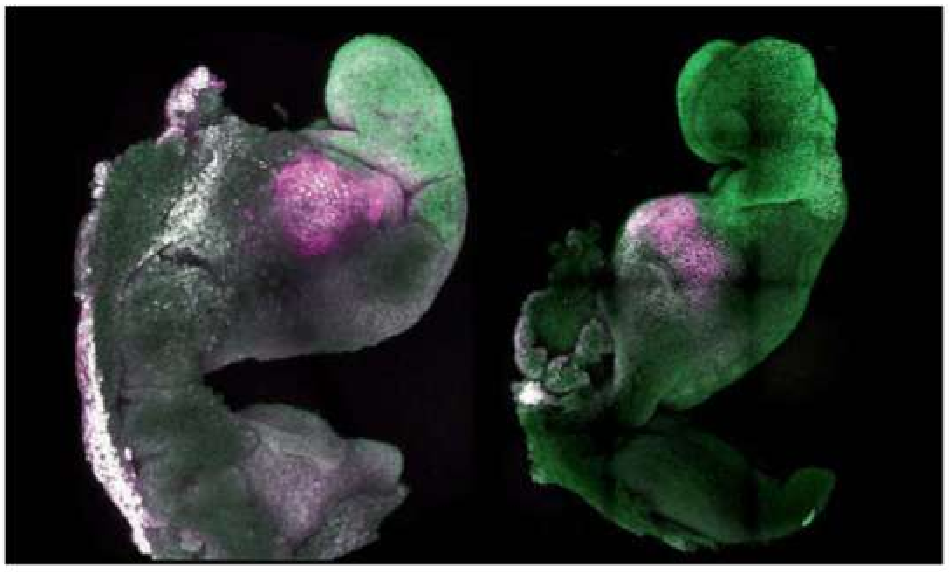
The result is an embryo-like structure that is the closest yet to a naturally developing embryo in the uterus, says Magdalena Zernicka-Goetz at the University of Cambridge, whose team is also using the same method to make synthetic human embryos, although these are less advanced.

The technique could lead to advances in creating tissues and organs for transplant and one day be used as a fertility treatment for people who cannot make sperm or eggs.

Human embryos can usually only be studied in a dish until they are about a week old because, at this stage, they normally implant into the placenta, which provides oxygen and nourishment. Also, most countries have a rule that human embryos may not be grown past 14 days, as after that they could be considered separate life forms.

In 2017, Zernicka-Goetz and her team announced they could create embryo-like structures that developed for several days. They did this by taking some stem cells from a mouse embryo and growing them alongside trophoblast cells, which normally go on to make the placenta. The method sparked worldwide interest as it would allow synthetic embryos to be created to order and genetically tweaked to improve our understanding of this mysterious stage of human development.

Synthetic (left) and natural (right) mouse embryos at 8.5 days



AMADEI AND HANDFORD

Now, Zernicka-Goetz and her team have made synthetic mouse embryos similar to real embryos 8.5 days after fertilisation by growing embryonic stem cells alongside two other kinds of helper cells, sourced from embryos (*Nature*, doi.org/h9cx).

Zernicka-Goetz says the part that becomes the brain is more advanced than in any previous approaches as it includes the developing forebrain. "This is the very first model system that can develop all parts of the future brain," she says.

The structures were cultured in a special rotating incubator with raised oxygen pressure. After 8.5 days, the synthetic embryos start to die, but the team is trying new approaches to help them survive longer.

If synthetic embryos could be made from human cells, in future, they could be used to create new sources of cells and tissues for transplant into people or for healing failing organs, such as the liver or heart. They could also be used to test medicines to see if they are safe for pregnancy, says Zernicka-Goetz.

Lluís Montoliu at the National Centre for Biotechnology in Madrid, Spain, said in a statement that the creation of synthetic embryos is as important as Dolly the sheep, the first mammal to be made by cloning an adult body cell. "We are undoubtedly facing a new technological revolution, still very inefficient, but with enormous potential," he said. ■

Optics

Anti-laser can make any object suck in light

INSERTING any material into a special maze of mirrors and lenses can make it absorb light almost perfectly. This approach could be used to detect faint starlight or to charge faraway devices with lasers.

Ori Katz at the Hebrew University of Jerusalem and his colleagues created an almost perfect light absorber by building an "anti-laser". In a laser, light bounces between mirrors until it becomes amplified enough to exit the device in a concentrated beam. According to co-author Stefan Rotter at Vienna University of Technology in Austria, in an "anti-laser", light enters the device and then gets stuck in an inescapable series of bounces within it.

The researchers achieved this by directing red light through a metre-long maze of carefully arranged lenses, mirrors and one piece of tinted glass – the item being turned into a light absorber. Light reflected off the mirrors and interacted with images of itself created by the lenses in such a way that it got redirected every time it came close to exiting the device.

On its own, the tinted glass could absorb 15 per cent of light. The whole device, in contrast, absorbed about 98 per cent, effectively increasing light absorption of the glass more than six-fold (*Science*, doi.org/h9c2).

Sahin Ozdemir at Pennsylvania State University says that, previously, similar devices perfectly absorbed only specific light wave shapes and only when they were illuminated at particular angles. The "anti-laser" works for all shapes, he says.

"In an 'anti-laser', light enters the device and then gets stuck in a series of bounces"

Ozdemir says the method could be used to collect light from very faint stars or to efficiently charge bigger devices with the energy of absorbed light, like charging a drone by hitting it with a laser.

However, Yidong Chong at Nanyang Technological University in Singapore says that the set-up may have to be miniaturised before it can be incorporated into useful devices. ■

Karmela Padavic-Callaghan

Evolution

Mucus has evolved at least 15 times in mammals

Corryn Wetzel

THE proteins that make mucus have evolved in at least 15 independent instances in mammals, possibly by co-opting existing proteins into becoming mucus-producers.

"Pretty much every animal [and] even yeast and bacteria have mucus," says Omer Gokcumen at the University at Buffalo in New York. "It's an essential-for-life kind of substance." Mammals produce mucus through toilet brush-shaped proteins called mucins.

Most animals have numerous mucins that combine to create the right thickness and slickness in different areas of the body.

Gokcumen and his colleagues performed a genetic analysis of 49 different mammals, from pangolins to rhinoceroses. They pinpointed 15 distinct mucins that weren't present in other species (*Science Advances*, doi.org/gqp6t8).

Finding one new mucin would have been surprising, says Gokcumen, but finding over a dozen was a shock. "They seem to be evolving independently in different lineages in different ways."

The researchers suspect the mucins are co-opted from existing proteins. By duplicating sections of specific amino acids, the proteins grow longer and transform into a slime-producing mucin.

Most species with unique mucins have just one, but others were standouts: ferrets have a total of five mucins unique to them alone.

Next, Gokcumen hopes to investigate how many times the slimy stuff has evolved in slugs and snails. ▌

SANDRA MAILER/SHUTTERSTOCK

Mucin proteins are a key ingredient in the saliva of mammals

Analysis Voting systems

Conservative party's online vote is vulnerable to hackers

Hacking concerns have dogged the Tory leadership contest in the UK. Should it ever have used online voting, asks **Matthew Sparkes**

JACOB KING – WPA POOL/GETTY IMAGES

Rishi Sunak and Liz Truss are vying to lead the UK Conservative party

A COMBINED online and postal vote will soon decide the UK's next prime minister, with the winner expected to be announced by 5 September, but doubts linger about whether the process is truly secure.

Early in August, the National Cyber Security Centre (NCSC) – a branch of UK intelligence organisation GCHQ – stepped in to delay the ruling Conservative party leadership poll while security for the online voting was tightened. It is the first time the UK prime minister will be chosen using online votes, and continued worries over hacking raise questions about whether online voting is a safe or wise choice when the stakes are so high.

Reports suggest that the race between Rishi Sunak and Liz Truss for the top job was delayed because of specific concerns. Party members were due to vote with a unique code that could be used by post or online, and they would be able to change their vote until polls closed. It was this "revoting" that the NCSC reportedly said represented a risk, and the ability has now been removed.

Steve Schneider, director of the Surrey Centre for Cyber Security at the University of Surrey, UK, says the NCSC was right to take an interest in the vote considering the possible implications of a hack. He says that online voting simply isn't ready for statutory elections yet.

"It is certainly plausible that hostile nation states might have an interest in affecting the outcome of this election if they were able to, and also that they have the capability to do so," he says. "They may be able to interfere by disrupting the election, either swinging the result in favour of their preferred candidate or casting doubt on the veracity of the result to undermine the legitimacy of the winner. These seem to be real possibilities that the system needs to guard against."

> "Hostile nation states might have an interest in affecting the outcome of this election"

The NCSC and the Conservative party didn't respond to requests for comment, but many nations run cyberattack teams and some of these seem to have been involved in influencing elections. Meanwhile, physical electronic voting machines already in use in the US have been found to have security vulnerabilities and to make unpredictable errors.

Election fraud was happening long before computers were invented, so it isn't much of a stretch to assume it will continue after polls move online. And given that government IT contracts are often changed, which can affect servicing schedules or software choices, there should be concerns about the reliability of voting machines or online services even without deliberate attacks.

The NCSC's intervention should have cut the risk of a cyberattack influencing the UK vote's outcome, but there may still be damage to public faith in online voting. For people to have trust in the political system, it is vital that elections not only work, but are also seen and believed to work. Public distrust in electronic voting could further undermine faith in politics.

Douglas Jones, a retired voting machine expert formerly at the University of Iowa, says making a vote public rather than secret is one way to guarantee safety, and if people want to keep details of who voted for whom secret, then computers aren't the way to go.

"You simply post all the votes in public where everyone can inspect the votes, and you provide a way for voters who object to the way their own votes were recorded with a way to correct them," says Jones. "I cannot see how to guarantee ballot secrecy without some form of physical ballot voted in the privacy of a voting booth. Paper is a particularly convenient form of physical ballot."

Ultimately, there is no such thing as an unhackable machine or service, and centuries of experience running votes with paper ballots means this remains the safest way to hold elections. ▌

Astronomy

Exoplanet CO_2 spotted for first time

The distant world WASP-39b may have formed similarly to planets in our solar system

Leah Crane

NASA's James Webb Space Telescope (JWST) has detected carbon dioxide in the atmosphere of a planet 700 light years away called WASP-39b. This is the first time the compound has been found in any exoplanet. The observations also suggest hints of a mystery within the distant world.

WASP-39b is huge. It has a mass similar to Saturn's and a diameter 1.3 times that of Jupiter. It orbits relatively close to its star, giving it an average temperature of 900°C, which puffs up the atmosphere, making it easier for JWST to see starlight shining through it.

When light from a star shines through a planet's atmosphere, molecules in the atmosphere absorb some of the light in unique wavelength ranges. Carbon dioxide absorbs infrared light, which is the same range JWST uses for its observations.

Natalie Batalha at the University of California, Santa Cruz, and a team of more than 100 researchers examined JWST observations, running them through four separate algorithms to be sure of the results. All four showed the clear signature of CO_2. "The carbon dioxide signature was just screaming at us," says Batalha. "It was honestly beautiful."

The result has a statistical significance of 26 sigma, meaning that the likelihood of finding such a signature as a statistical fluke is less than 1 in 10^{149}. "It's just exquisite," says Eliza Kempton at the University of Maryland, part of the research team. "I've never seen anything like 26 sigma in this field."

Artist's impression of the exoplanet WASP-39b orbiting its star

NASA, ESA, CSA, AND J. OLMSTED (STSCI)

The researchers found that WASP-39b has more carbon and oxygen than its host star, implying that it didn't form when gas around the star collapsed all at once, but rather its rocky core formed first and then accreted the gas that makes up its atmosphere. This is similar to how we think the planets in our own solar system formed. Studying the exoplanet's atmosphere could reveal more about how and where it formed (arXiv, doi.org/h9c4).

Aside from carbon dioxide, the researchers found another bump in their data, indicating that something unexpected in WASP-39b's atmosphere was absorbing some of the starlight. "There's something else there, some other molecule or some kind of cloud or haze – something that's not predicted by the basic model" of exoplanet atmospheres says Kempton. The researchers aren't sure yet what this mystery molecule may be, but they are working to figure it out with additional data from JWST and different models.

The fact that we were able to see carbon dioxide in this gas giant's atmosphere is a good sign for our ability to eventually understand the atmospheres of rocky worlds similar to Earth, one of the main goals of JWST, says Batalha.

It may also be useful in the hunt for alien life. "Down the road, it may be an interesting biosignature when found in combination with other molecules like methane," says Jessie Christiansen at the NASA Exoplanet Science Institute in California. ▮

Mathematics

The complex rules of wrinkling have been worked out

WE NOW know the rules for wrinkling, at least in certain circumstances. Using experiments, simulations and mathematical proofs, researchers have worked out how very thin curved shapes wrinkle when flattened.

Pinning down the mathematics of wrinkling is surprisingly hard. As something wrinkles, its properties change and so mathematical models of the situation must constantly change as well.

To try to better understand how the process works, Eleni Katifori at the University of Pennsylvania and her colleagues investigated how curved pieces of a plastic material thousands of times thinner than a human hair wrinkle. The team chose this scenario because thin materials wrinkle particularly well and Katifori could simulate them on a computer.

Originally, the researchers couldn't predict any wrinkling patterns. The breakthrough came when they realised Ian Tobasco at the University of Illinois at Chicago had already independently developed a mathematical theory based on the energy cost of certain patterns of wrinkles and they could team up to refine it. Through a back-and-forth between experiments, simulations and mathematics, they turned the theory into wrinkling rules for different shapes.

They found that whether wrinkles form in rows of ripples or only on the edges of the plastic depends on the shape of its curve. For instance, saddle-like shapes stay smoother at their centre than sphere-like ones.

"Pinning down the mathematics of how things wrinkle is surprisingly hard"

The researchers also found they could predict where wrinkles would form by splitting shapes into smaller sub-shapes. Tobasco's mathematics then provided rules for what kind of ripples would show up in each of those smaller sections (*Nature Physics*, doi.org/h9cz).

Robert Kohn at New York University says that predicting wrinkling patterns on a thin sheet is mathematically so complex that it is surprising to see the researchers determine any rules at all. ▮

Karmela Padavic-Callaghan

Technology

Ageing can play havoc with face-recognition systems

Matthew Sparkes

WE CAN age as little as five years before face-recognition algorithms begin to struggle to identify us as the same person. This means systems that rely on facial recognition may need to get new images of users more often.

Face recognition is now used at border crossings, by police to watch for known offenders in public and even to unlock our phones. But there has been little research on how such systems cope with faces changing over time. So, Marcel Grimmer at the Norwegian University of Science and Technology and his colleagues designed a test to assess this.

The team used open-source alternatives to face-recognition tools used by police forces and smartphone makers, which don't reveal how their own algorithms work, and also used AI-generated images of 50,000 people aged artificially to various degrees, due to the scarcity of real data sets collected over long time frames.

Grimmer says the accuracy of face-recognition systems dropped continuously over time from when the reference image was taken, rather than suddenly. Within five years, they usually identified people, but after that, they began to struggle. Gaps beyond 20 years proved difficult for the systems (arxiv.org/abs/2208.08207).

He says faces will age differently depending on lifestyle factors and stage of life, so knowing how often face-recognition systems need to update photos of users is hard.

"Babies will change within two months. Generally, even until the age of 20 years, the face still kind of changes," says Grimmer. Then, from about 20 to 60, the identity is more stable and there will only be some texture changes, like wrinkles. After that, the face shape begins to shift again, and you have more pronounced wrinkles, he says. ▮

Medicine

Mutation-inducing drugs could raise virus dangers

Michael Le Page

THE use of antiviral drugs that kill viruses by inducing lots of mutations should be restricted because of potential dangers highlighted by new research, some researchers say. Computer modelling suggests these drugs could result in viruses acquiring changes they wouldn't do otherwise and in a way that lab testing will miss.

All organisms continually mutate and most of these mutations are detrimental. Harmful mutations are normally eliminated from populations by natural selection, but if the rate of change is high enough, natural selection cannot get rid of mutations fast enough to prevent them building up to lethal levels and killing entire populations.

Mutagenic drugs are designed to raise mutation levels in viruses or cancer cells and produce such a "mutational meltdown". Several mutagenic drugs are in use, including molnupiravir, which is used to treat covid-19. The drugs consist of molecules that mimic the building blocks of RNA and get added to the RNA genomes of viruses when they replicate, inducing mutations.

"Such complex mutations could have effects that are advantageous to the virus"

Using a model, Claudia Bank at the University of Bern in Switzerland and her colleagues assessed several potential ways for viruses to evolve resistance to these drugs. The most surprising finding is that changes that make viruses more susceptible to the effects of harmful mutations could, in very rare cases, help them escape meltdown.

Medicines in a drugstore in Miami, Florida

JEFFREY ISAAC GREENBERG 13+/ALAMY

This can happen because a higher susceptibility to harmful mutations also makes natural selection more effective at removing harmful mutations. But this susceptibility must evolve very early on or a virus population will already have accumulated enough harmful mutations to drive it extinct.

The model suggests this would be so rare that the escape mechanism would be unlikely to be seen in lab testing and human trials before a drug is approved, but it could occur if a drug is given to millions of people (bioRxiv, doi.org/h9cr).

If this happened while a person was being treated, the risk wouldn't just affect them. A virus that survives treatment with a mutagenic drug could acquire a lot more mutations than it would otherwise, potentially leading to the evolution of more dangerous variants that could spread widely if they went on to infect other people.

"Such complex mutations could outrun the human immune system or have other effects that are advantageous to the virus," says Bank.

The risks will be even higher if people miss doses or fail to complete drug courses, she says. "I would suggest that mutagenic drugs should only be administered in hospitals and doctors' practices such that doses and administration intervals are monitored," she says. "As regularly happens with antibiotic treatments, patients are likely to forget to take the drug or to stop treatment prematurely when they feel better, if they are allowed to administer it by themselves."

William Haseltine at global health think tank ACCESS Health International says the study's conclusions seem accurate, but confirming them will require experimental observations.

A spokesperson for Merck, which makes molnupiravir, says: "History has shown that insights made solely from computational modelling experiments require careful evaluation and interpretation when compared to findings from studies conducted in living systems." ▮

Technology

Underwater data centre set for Pacific

Jeremy Hsu

AN UNDERWATER data centre could start operating off the west coast of the US before the end of 2022. The project is an attempt to show the viability of using the ocean to provide cooling, which normally accounts for a large portion of data centre energy use.

"By placing the data centres subsea, we eliminate the electrically driven cooling which is 40 per cent of the power consumption," says Maxie Reynolds, co-founder of Subsea Cloud, the firm behind the project. "If you eradicate 40 per cent of the power consumption, you do the same to the carbon emissions."

Subsea Cloud has designed a modular data centre consisting of steel pods the size of shipping containers. Each pod can hold 16 standard server racks filled with about 800 computer servers.

Unlike most land-based data centres, the servers in a pod are directly immersed in a special fluid similar to mineral oil that doesn't conduct electricity. Excess server heat passes to the fluid, through the pod's walls and then into the surrounding ocean.

Deploying a pod involves the help of a surface ship equipped with two remotely operated vehicles and a subsea digging machine. Servers typically need to be replaced every three to five years, which would be done by periodically swapping out pods.

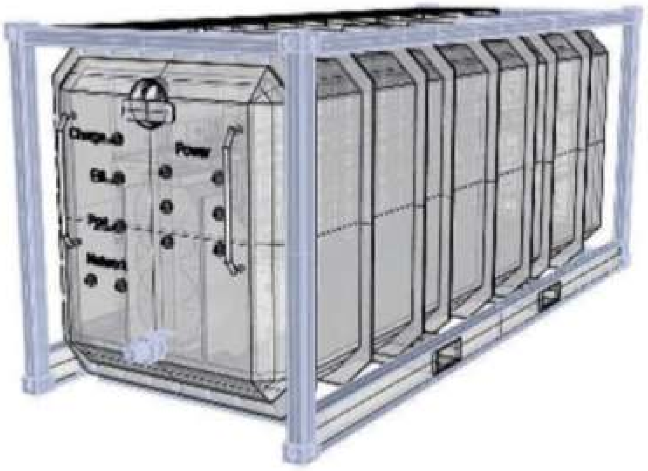
Subsea Cloud plans to build its first commercial data centre at Port Angeles in Washington state at a depth of 9 metres, starting with one pod within sight of the port and potentially scaling up to 100 pods. It will be able to perform all the usual functions of a data centre, such as storage and computational processing.

The excess data centre heat could raise the water temperature within the immediate vicinity, says John Abraham at the University of St. Thomas in Minnesota. However, it would have a "negligible effect on ocean warming" and could actually help reduce global warming because of the reduced power requirements.

40%

The share of energy used for cooling at a data centre

The start-up isn't alone in pursuing this idea. Beijing Highlander Digital Technology Company plans to build an underwater data centre consisting of 100 modules near China's Hainan Island, after previously testing a single module holding four server racks in 2021. Microsoft has also tested prototypes, although it isn't currently pursuing the idea. ▮



SUBSEA CLOUD

A drawing of one of Subsea Cloud's data centre pods

Marine biology

Bacteria seep out from cracks in the sea floor

James Dinneen

HEAT-LOVING, petroleum-eating bacteria that live deep beneath the sea floor have been found seeping out into the ocean. They may then float around in a dormant state before coming back to life in other distant oil reserves.

As much as 45 per cent of all microbes live underground in hot rocks, subsisting on hydrocarbons and other chemical energy. This "deep biosphere" is the largest habitat on Earth, yet little is known about its ecology, says Casey Hubert at the University of Calgary in Canada. "You can't put a radio collar on a microbe and follow it around like you would with a grizzly bear."

Hubert and his colleagues used a combination of acoustic surveys and genetic analysis to better understand how bacteria from the deep biosphere get around. With an autonomous submarine equipped with sonar, the researchers found a section of the continental shelf south-west of Nova Scotia where petroleum was seeping out of cracks and into the ocean. They then took scoops of mud from 14 sites on the sea floor.

Heat-loving bacteria – known as thermophiles – can become dormant spores when they are exposed to cold. To identify any thermophilic spores in the samples, the researchers heated them in the lab to 80°C (176°F). "That kills most of the stuff," says Hubert. "But the spores wake up and start to have quite a party." Some spores can remain viable in hostile environments for thousands and possibly millions of years.

The team sequenced portions of the revived bacteria's DNA. The microbes in the samples that contained petroleum were distinct from those found in samples without petroleum. They also had genes enabling them to break down petroleum.

The team then examined drilling samples from petroleum reserves thousands of metres underground and found they contained the same kinds of petroleum-eating microbes (*Science Advances*, doi.org/h9nv).

The finding is "very beautiful evidence" that the bacteria had been carried to the sea floor from deep in the planet within "petroleum seeps", a process that can take decades to hundreds of years, says Juan Höfer at Pontifical Catholic University of Valparaíso in Chile.

The bacteria's journey probably doesn't end there. Ocean currents could move the dormant bacteria elsewhere on the sea floor, with some travelling thousands of kilometres away, says Hubert.

Returned to the sea floor, the spores would then be buried in sediment, sinking to hotter depths over millions of years. If they were lucky enough to land on a petroleum deposit, the dormant spores might then come alive again, says Hubert.

Rika Anderson at Carleton College in Minnesota says this "microbial dispersal loop" could help explain why bacteria found in petroleum reserves separated by thousands of kilometres share more genes than bacteria in different environments nearby. ▮

NATURE PICTURE LIBRARY/ALAMY

Kelp on the sea floor off Nova Scotia, Canada

Physics

Best evidence yet that the mysterious 'chameleon' force doesn't exist

Alex Wilkins

A TEST to measure a leading candidate for dark energy, a fifth fundamental force called the chameleon force, has found no evidence that it is real. The researchers behind the test say this rules out the basic chameleon model as an explanation for dark energy, but some people think it could still play a role.

Dark energy has been suggested as an explanation for the observation that galaxies appear to be accelerating away from each other. One possible candidate for how it works is the chameleon force, an additional fundamental force to the four we know are at work in the universe: gravity, the strong force, the weak force and electromagnetism.

The strength of the chameleon force would depend on the density of matter around it. In less dense regions of space over cosmic distances, it would force matter apart. But on Earth, which is a dense region by cosmological standards, it is so small it would be dwarfed by the other forces, making it difficult to measure.

People have tried to detect the chameleon force before by measuring any displacement between a test mass and groups of atoms in a lab, or between a test mass and a pendulum, but limitations in the size or scope of those experiments mean that the force might still have been lurking at energy scales we couldn't probe.

Now, He Jian-hua at Nanjing University in China and his colleagues have devised an experiment that uses a magnetically levitated strip of graphite and a test mass to look for evidence of this mysterious effect at scales that fill in the gap between the past pendulum and atom experiments.

A. SCHALLER (STSCI)/ESA

The chameleon force may have been crucial in the early universe

He and his team tried to minimise every other possible force by having masses so thin that the effect of gravity on them is negligible, and placing the test mass inside a Faraday cage, which blocks out electric fields. They then used an optical microscope and a laser system to measure any chameleon-driven displacement between the two masses (*Nature Physics*, doi.org/h9ct).

"If dark energy really exists, then in our experiment we should be able to detect [the chameleon force]," says He. "We have a very sensitive force sensor, but we found nothing."

The result is important for narrowing down the scales and energies at which a chameleon force might act, says Jeremy Sakstein at the University of Hawai'i at Manoa. However, it doesn't rule out possibilities for its existence if dark energy works at different energy scales, he says.

While their work has made a link between the chameleon force and dark energy more unlikely, a chameleon force unrelated to dark energy could still exist, says Adrienne Erickcek at the University of North Carolina at Chapel Hill.

The researchers hope to improve their apparatus by cooling it to very low temperatures so they can further probe the chameleon idea and test other dark energy candidates. ▮

Technology

Short ads could guard against fake news on YouTube

PLAYING short educational animations in the adverts before YouTube videos can make us more conscious of the techniques used to disseminate misinformation. Doing this widely might reduce the spread of misleading claims.

Jon Roozenbeek at the University of Cambridge and his colleagues have created a series of 90-second videos highlighting the ploys that peddlers of online conspiracies and fake news use. Their idea was to "pre-bunk" (rather than debunk) disinformation by arming people with skills to help them identify falsified or manipulative content.

The researchers tested the videos on about 6400 people in the lab, having participants watch videos that showed how misinformation can be passed on, including by the use of emotional language, false dichotomies, scapegoating and character assassinations.

Surveys revealed that those shown a pre-bunking video rather than an unrelated video were more attuned to disinformation tactics.

The researchers then showed 5.4 million US YouTube users pre-bunking videos before the videos they had clicked on to view.

Nearly 1 million people watched the 90-second videos for at least 30 seconds. About 30 per cent of these were then asked to identify a manipulative method in a sentence they were shown. Watching a pre-bunking video improved their ability to identify such techniques by 5 per cent compared with people with no pre-bunking exposure (*Science Advances*, doi.org/gqp2r8).

"These videos have a measurable and meaningful effect in the real world" — pull quote

"These videos have a measurable and meaningful effect in the real world," says Roozenbeek.

"These findings are exciting because they demonstrate that we can scale pre-bunking... using ads as a vehicle," says Beth Goldberg at Jigsaw, a unit within Google – which also owns YouTube – dedicated to tackling threats to society.

Google is now launching a pre-bunking campaign in Europe to counter anti-refugee narratives. ▮

Chris Stokel-Walker

Evolution

How fungi's weird shapes evolved

Two distinct bursts of increasing complexity led to the many forms fungus species take

Jake Buehler

THE wild array of anatomical variety in fungi – from the thread-like tangles of some mould species to colourful mushrooms with dazzling caps – has its roots in two distinct bursts of evolution hundreds of millions of years ago. These big jumps in variation seem to be linked to evolutionary boosts in the number of traits that make up each species, known as an organism's complexity.

Detailed analyses of anatomical complexity are limited, says Thomas Smith, who is now at the University of Oxford. "They've pretty much exclusively been done on the animal kingdom," he says. Smith and Philip Donoghue at the University of Bristol, UK, analysed patterns of anatomical variation – known as disparity – in fungi, the closest kingdom-sized branch to animals on the tree of life.

The pair created a data set based on more than 300 physical traits at cellular and multicellular scales from 44 species across the fungi kingdom. They then compared the evolutionary relationships between the species with how their physical features were related to each other, and used computer simulations to recreate how disparity in fungi changed over millions of years.

They found four major fungi groups that have similar cellular features. These include the flagellated group, which have sperm-like cells, and the zygomycetous fungi, which produce spores from the fusion of two sex cells. Then there are sac-bearing and club-bearing fungi, to which the grand diversity of fruiting bodies – such as mushrooms – belong.

This variation didn't develop all at once, or continuously over the past billion or so years of fungus evolution, but seems to have occurred in two distinct bursts associated with jumps in multicellular complexity.

The first occurred roughly 800 million years ago, when the first multicellular body plans in fungi evolved from flagellated ancestors. Then, between about 500 million and 300 million years ago, a series of spikes in new variation arose when the strange shapes of fruiting bodies came into their own (*Nature Ecology & Evolution*, doi.org/h9pr).

Surprisingly, says Smith, there doesn't seem to be a link between expansions of the fungal genome – the set of genetic instructions – and shifts in anatomical variation.

Plotting a "morphospace" for fungi, which shows species as dots that are closer together the more similar they are in physical anatomy, the researchers found that the major groups of fungi cluster as four distinct islands without overlapping.

Between the clusters is empty morphospace that might once have been filled by now-extinct species. "Maybe the picture was once more complete," says Smith. "Maybe it was more of a splat [shape] rather than a couple of drops in an ocean of morphological possibility." ▮

***Dasyscyphella nivea*, a cup fungus that belongs to the sac-bearing group**

ANDY SANDS/NATUREPL

Turn to page 30 to see a dramatic image of a parasitic fungus

Health

Psychedelic therapy helps some people quit alcohol

PSILOCYBIN, the psychedelic component of magic mushrooms, may help people with alcohol dependencies stop drinking.

Michael Bogenschutz at NYU Langone Health in New York and his colleagues recruited 95 adults diagnosed with alcohol dependence for a 12-week therapy programme. The participants had no major psychiatric conditions and hadn't used psychedelics in the past year. Most weeks, they had a cognitive behavioural therapy session with a therapist and a psychiatrist.

In weeks 4 and 8, everyone had an 8-hour session where they were encouraged to lie on a couch, wear an eye mask and listen to music. During these sessions, 49 people received a 25-milligram dose of psilocybin per 70 kilograms of body weight, which is considered enough to cause hallucinatory effects. Forty-six received an antihistamine placebo, as it can cause similar side effects to psilocybin, such as relaxation and drowsiness.

Prior to the study, participants reported drinking heavily on 53 per cent of days, on average, consuming at least four alcoholic drinks a day for women and at least five a day for men. From the start of the study to week 32, the average number of days people reported drinking heavily decreased in both groups, down to 9.7 per cent of days for the psilocybin group and 23.6 per cent for the antihistamine group. By 36 weeks, 47.9 per cent of the psilocybin group and 24.4 per cent of the antihistamine group reported they had quit drinking entirely (*JAMA Psychiatry*, doi.org/h88b).

"The mechanism behind the effect is unclear, but psychedelics may increase the brain's ability to adapt"

The mechanism behind the effect is unclear, but animal studies have shown that psychedelics may increase the brain's ability to change and adapt, says David Yaden at Johns Hopkins University in Maryland. One caveat of the study, however, is that more than 90 per cent of participants correctly guessed which drug they had been given. Their expectations could have influenced the results. ▮

Grace Wade

Computing

Squishy computer calculates based on how you squash it

Karmela Padavic-Callaghan

SOFT, cube-shaped computers can do different calculations depending on how they are squished. The devices could be used for robots that respond to physical stimuli.

Ryan Harne at Pennsylvania State University and his colleagues developed a technique for combining rows of rubber blocks that have lines of a silver-rubber compound running through them. Different configurations of the blocks act like different circuits, which, when combined and connected to electricity, make a computer that can perform particular calculations.

In one version of the computer, the team set it up to add together two numbers. A user would then tell the computer which numbers to add by squishing the component blocks to the left or to the right, connecting some of the silver-rubber lines that didn't touch before in such a way as to encode the numbers in binary. The team connected a (non-squishable) digital display to it to show the result of the calculation.

The researchers also created squishy computers that could multiply two numbers or compare them to determine which is greater (*Nature*, doi.org/h9c5).

Ryan Hayward at the University of Colorado Boulder says that squishable computers wouldn't beat conventional ones by being faster or solving harder problems, but they could lead to soft robots that make decisions based on what they touch in their environment.

In the future, Harne imagines a soft computer that is integrated into a building. It could "decide" to repair the building after a crumbling piece of rock applies pressure to it.

The team is working on fine-tuning the computer's "sense of touch" so that it can take inputs beyond the binary, for example by having it encode different squishing strengths into different values. ▮

Palaeontology

Two-legged dinosaur is the oldest ever found in Africa

Ryan Truscott

MURPHY ALLEN

Team members work at the dig site in Mbire, Zimbabwe

THE remains of a new species of plant-eating dinosaur have been unearthed in northern Zimbabwe. It is part of a huge assemblage of fossils from the Late Triassic that could help us understand how the period's climate influenced the dispersal of early dinosaurs.

The near-complete fossil is the oldest dinosaur fossil found in Africa to date. It has been identified as a species of sauropodomorph, ancestral relatives of the sauropods – the huge, long-necked dinosaurs that walked on four legs.

Named *Mbiresaurus raathi,* the dinosaur stood at least a metre tall, ran on two legs, weighed around 30 kilograms and had a small head, a long neck and serrated, leaf-shaped teeth.

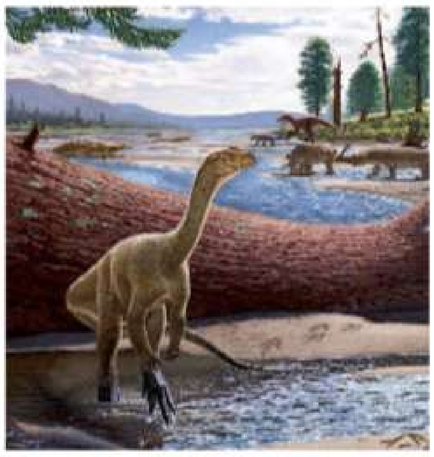
It was unearthed on the second day of an expedition to Mbire in the Zambezi valley in 2017, says Christopher Griffin at Yale University, who found a dinosaur femur sticking out of the ground, dug around it and discovered a hip bone.

"I kept digging, got more of the team to help out, and we recovered nearly the entire skeleton," he says. "The rocks it was found in have been interpreted as a river deposit, and it may have been buried in a small-scale flood."

Based on the presence of other fossils in the assemblage, the team has dated *M. raathi* to around 230 million years ago, part of the Late Triassic called the Carnian stage. At that time, what is now Zimbabwe was much further south than it is today, and part of the massive supercontinent Pangaea.

Latitude played a big role in Pangaea's climate, scientists suggest, because of the reduced influence of the sea on the single landmass. Higher latitudes, like those at which Zimbabwe was located at the time, probably had greater humidity and abundant vegetation, in contrast to the more arid, unstable lower latitudes.

Artistic reconstruction of *Mbiresaurus raathi*



ANDREY ATUCHIN

These climatic bands are thought to have controlled the range of early dinosaurs, with most living within the temperate climate of southern Pangaea. Dinosaurs are thought to have avoided the harsh deserts to the north of this zone, to which they weren't well-adapted.

The site in Mbire yielded hundreds of bones, including those of a large carnivorous herrerasaurid dinosaur, ancestors of mammals called cynodonts and crocodile ancestors called aetosaurs (*Nature*, DOI: 10.1038/s41586-022-05133-x).

Anusuya Chinsamy-Turan at the University of Cape Town, South Africa, says the find provides a unique glimpse into the faunal diversity that existed in that part of northern Zimbabwe 230 million years ago.

"The fact that the fauna resembles other similar-aged Carnian deposits in Argentina, as well as in Brazil and India, strongly supports the hypothesis that the distribution may be linked to climatic barriers," she says.

The new Zimbabwean fossil find comes as Australian firm Invictus is this month expected to begin exploratory drilling for oil and gas across a vast section of the Cabora Bassa basin, the area in which the fossil-rich rocks are deposited. ▮

Neuroscience

Rapid eye movements during sleep reveal where mice look in dreams

Clare Wilson

HAVE you ever wondered what animals dream about? When mice slumber, their rapid eye movements reflect the imagined movements of their heads in their dreams.

If the same is true for humans, researchers may be able to observe people walking around in their dreams by tracking their eye movements.

During a night's sleep, people progress through different stages, from light dozing to heavy slumber. This includes several periods known as rapid eye movement (REM) sleep, when their eyes move jerkily from side to side.

REM sleep is also when we have our most vivid dreams, something discovered in the 1950s. But it has long been unclear whether the accompanying eye movements have any significance or if they are entirely random.

Yuta Senzai and Massimo Scanziani at the University of California, San Francisco, wondered if they could shed some light on this by putting electrodes into the brains of mice to record the firing of neurons that keep track of the orientation of the head.

> "This answers a long-standing question about whether eye movements in REM sleep are random"

They first recorded the firing of these neurons while the animals were awake and moving around. Using a camera fixed to the top of the head, they found that the mice's head movements to the left or right were accompanied by fast, jerky movements of their eyes in the same direction.

The amount that their eyes moved to the left or right also tallied with the degree to which their heads turned.

The researchers continued recording when the mice fell asleep – luckily, mice sometimes sleep with their eyes open. Sure enough, when the animals entered REM sleep, their jerky eye movements also correlated with the firing of the head-direction brain cells. In effect, the team could decode the mice's dreams, at least to the extent of knowing which direction they were looking in (*Science*, doi.org/gqp3f6).

"We were happy to see you can predict the change of head direction and its amplitude. It was pretty surprising," says Senzai.

This suggests that, in future, researchers could decode this aspect of rodents' dreams without having to put electrodes into their head, just by tracking their eye movements, says Senzai.

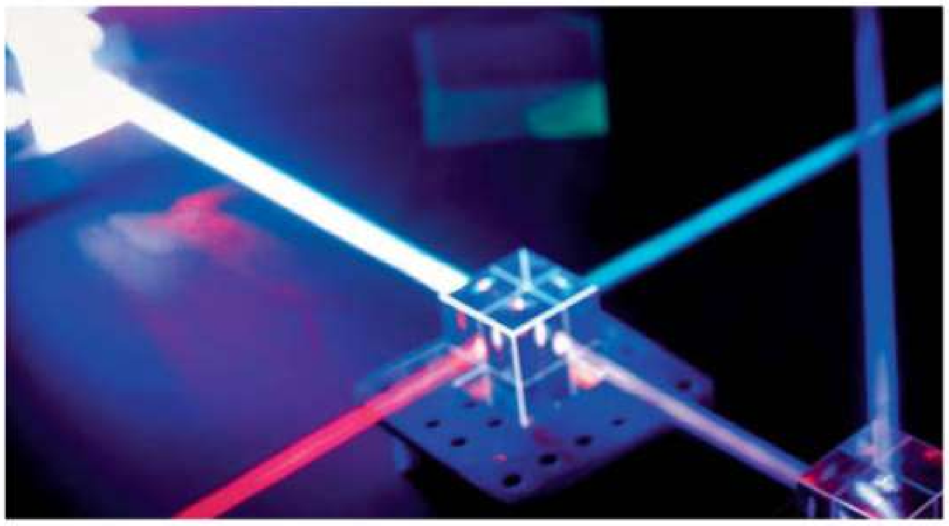
Cathrin Canto at Erasmus University Medical Center in Rotterdam, the Netherlands, says the finding answers a long-standing question about whether eye movements in REM sleep are random – and could allow better understanding of human dreams.

Previous work in which electrodes were put into the brains of rodents has shown that, during sleep, they "replay" their movements around a laboratory maze, and this appears to help them to memorise its layout.

Something similar seems to go on in humans, and eye movements of people can be tracked while they sleep by placing electrical pads next to their eyes, avoiding the need to do brain surgery. "It opens up new fields of research," says Canto.

Physics

Plasmas could help make the world's most powerful laser



SHUTTERSTOCK/LUCHSCHENF

Laser beams could be much more powerful if passed through patterned plasma

USING plasma to create lasers could make them thousands of times more powerful than the strongest ones that currently exist.

Matthew Edwards and Pierre Michel at Lawrence Livermore National Laboratory in California have proposed a laser design that includes components made from plasma, a state of matter similar to a hot "soup" of charged particles.

"As lasers produce more and more power, they have a tendency to destroy themselves," says Edwards. "But we can put a lot more light on a plasma without damaging it, anywhere from 100 times to as much as a million times."

They mathematically modelled a laser where a component called a transmission grating, usually made of glass-like materials such as silica coated in gold, would instead be created by shooting smaller lasers into gas to make a specially patterned plasma. Like conventional lasers, lenses and mirrors would help produce a beam of light, but passing the beam through the plasma grating would turn it into a very quick and intense pulse of light (*Physical Review Applied*, doi.org/gqn75b).

The most powerful existing lasers require metre-sized transmission gratings and can output tens of petawatts of power over a quadrillionth of a second. Edwards says plasma lasers could produce equally powerful beams with plasma gratings 1.5 millimetres in diameter. Using even larger gratings could lead to the creation of unprecedentedly powerful lasers.

David Turnbull at the University of Rochester in New York says the new design is compelling, but that controlling and confining plasma inside a device is an engineering challenge. However, he says, the design presents an opportunity to push the frontier of laser power and intensity forward, maybe even as far as being able to use very intense laser pulses to "rip" empty space into pairs of particles and antiparticles.

Karmela Padavic-Callaghan

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Human evolution

Fossils hint at origins of bipedalism

An analysis of thigh and forearm bones suggests that early ancestors of humans began walking on two legs much earlier than we supposed, reports **Clare Wilson**

THE ancestors of humans may have been walking on two legs by about 7 million years ago – a million years earlier than had been thought. But the finding, which comes from analysing a damaged thigh bone and two forearm bones, is controversial.

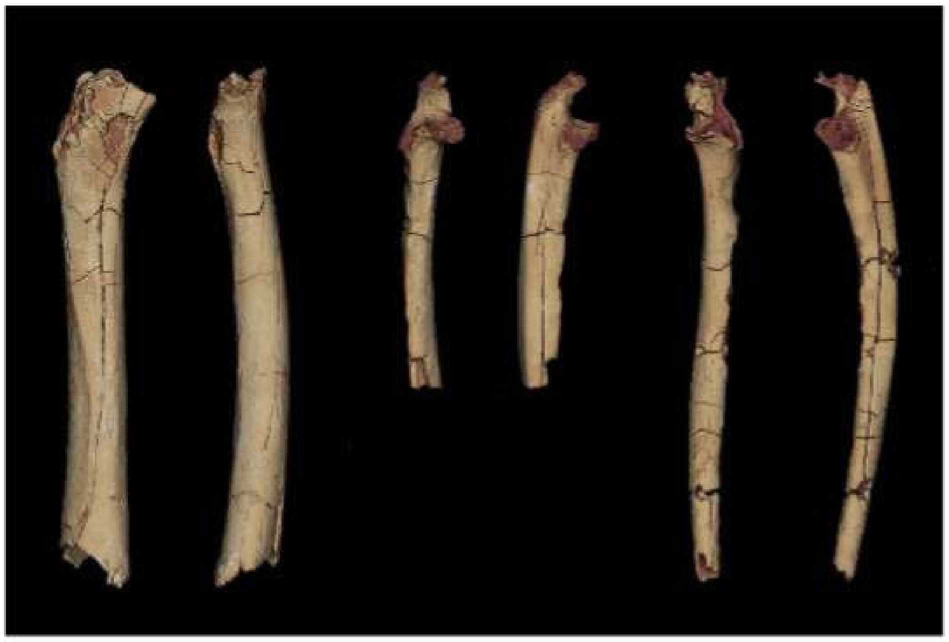
Estimates vary for when the ancestors of humans and chimpanzees split from each other but broadly converge on about 6 million years ago. This is also the age of the earliest fossil of a hominid recognised as bipedal, called *Orrorin tugenensis*.

The bones analysed in the latest study were discovered in the Djurab desert in Chad. They were among thousands of bone pieces initially uncovered in 2001, almost all of which weren't from primates.

The first hominin fossils identified among the bone pieces were fragments of skull and a few teeth. These were identified as a new and very early hominin species named *Sahelanthropus tchadensis*, dating from about 6 to 7 million years ago. A later method of fossil dating, based on analysing different forms of the element beryllium, pushed this estimate back to somewhere between 6.5 and 7.5 million years ago.

In 2004, Aude Bergeret-Medina and Roberto Macchiarelli at the University of Poitiers in France identified one of the bone pieces as a thigh bone, or femur, potentially also belonging to a hominin. They later lost access to it, but in 2020 they published work based on measurements and photographs that argued that its shape suggests the owner didn't walk on two legs.

Now, Franck Guy, who is also at the University of Poitiers, and his colleagues – who still have access to the fossils – have published a full analysis of the femur as well as two forearm bones, or ulnae, including computed tomography scans to see their internal structure. It took so long partly because the team didn't initially have the right expertise to analyse bones other than the skull, says Guy.


FRANCK GUY/PALEVOPRIM/CNRS – UNIVERSITY OF POITIERS

MPFT/PALEVOPRIM/CNRS – UNIVERSITÉ DE POITIERS

3D models of the femur and ulnae of *Sahelanthropus tchadensis*, above, and the Djurab desert in Chad where the bones were found, left

> **"Unless you have a time machine, you can't go back and see for yourself how they moved"**

It is unknown if all the hominin bones came from the same individual or from several, but the researchers have assumed they belong to *S. tchadensis* as this was the only large primate with bones found at the site.

The researchers compared the *S. tchadensis* femur and ulnae with those from modern humans, as well as chimpanzees, gorillas, orangutans and some extinct hominins and great apes.

They conclude that *S. tchadensis* spent some time clambering in trees but usually walked on two legs, based on several features of the femur that they say are closer to those of modern humans than great apes that usually walk on four limbs. These include the distribution of thicker sections of the dense outer layer of bone, called the cortex, and the presence of a rough surface at the top of the femur where the buttock muscles attach (*Nature*, doi.org/h87c).

"When on the ground, they would have preferred to move bipedally," says Guy. "[When in trees] they would sometimes choose to use clambering. All the features point to this kind of behaviour."

But Macchiarelli isn't convinced. This is partly because he says the angle the femur makes with the pelvis would be "mechanically unstable for a vertical stance".

Mixed locomotion

Other primates that mainly walk on four legs occasionally stand up and walk on two, which could be why *S. tchadensis* has some features of bipedalism, says Macchiarelli. "There's a bipedal signal in any primate," he says.

However, Guy says their conclusions are based not on individual aspects of the bone, but its overall suite of features.

Fred Spoor at the Natural History Museum in London says the authors "make a good case" for bipedalism, but the debate is likely to continue. "Unless you have a time machine, you can't go back and see for yourself," he says.

The question is an important one because more recent hominins, such as the australopiths, both walked on two legs and climbed in trees as recently as 3 to 4 million years ago, he says. "That would mean that for the first 3 million years [of our history], there was this mixed locomotion, and not much was happening."

Kelsey Pugh at the American Museum of Natural History in New York says it would be useful to compare the *S. tchadensis* femur with a wider range of living and extinct primates. "It will be vital for independent teams of palaeoanthropologists to study these exciting fossils in the coming months," she says. ■

For more on human evolution, turn to page 46

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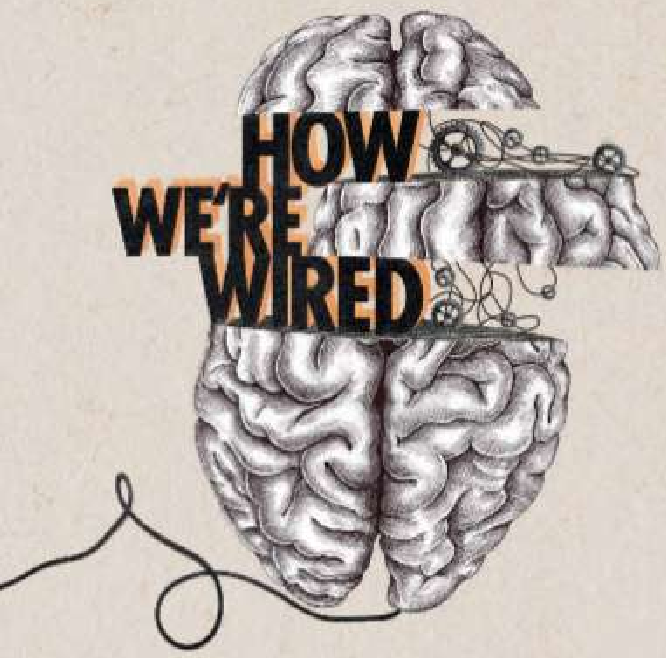

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Astronomy

See the gas giant glow

The James Webb Space Telescope has taken an incredible image of Jupiter

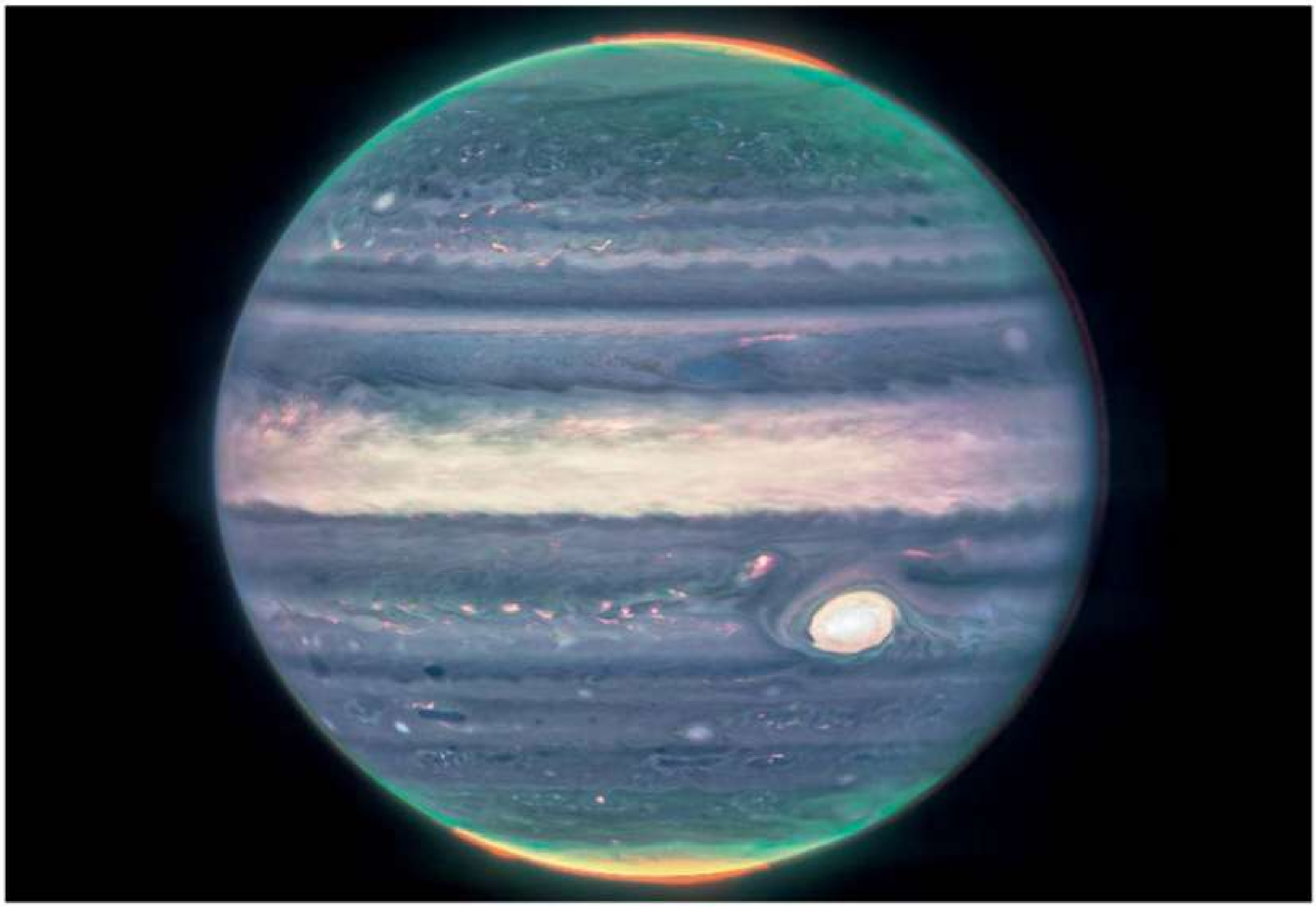
Leah Crane

THIS stunning James Webb Space Telescope (JWST) image reveals the complexities of Jupiter. While the telescope's previous images of the gas giant used only one wavelength of light, this is a composite, showing its glowing auroras, shifting haze and two of its small moons.

Because JWST observes in infrared light, the image doesn't show Jupiter as it would look to the naked eye. Instead, different infrared wavelengths have been mapped to different colours to highlight particular features.

The orange glow at the poles is Jupiter's aurora. The green represents layers of tenuous high-altitude haze, while blue shows the main cloud layer. The white areas show the tops of storms, including the Great Red Spot.

"We hadn't really expected it to be this good," said Imke de Pater at the University of California, Berkeley, in a statement. ▮



NASA, ESA, CSA, JUPITER ERS TEAM/JUDY SCHMIDT

Technology

AI-created lenses let camera ignore objects

A CAMERA equipped with 3D-printed plastic lenses designed by artificial intelligence can take photographs that capture only certain objects and ignore everything else in the frame. The selective lenses use no power and instead rely on complex patterns printed into the plastic to diffract light in different ways.

Aydogan Ozcan at the University of California, Los Angeles, and his colleagues trained a deep-learning AI model to recognise images of numbers from a huge online repository of handwritten digits inside a simulation. Some numbers were designated as targets to appear in images, some as objects to ignore.

The AI was shown thousands of images, one at a time, and told when those that were supposed to reach the camera's sensor did and didn't pass through a series of three lenses, as well as when numbers that weren't meant to reach the sensor did. The AI tweaked its lens design to better achieve the desired effect.

Once the model had a working solution in the simulation, the lenses were 3D printed with clear plastic and tested in the lab on new images of numbers.

Each target image was placed in turn between the AI-designed lenses and a terahertz radiation source that was used instead of visible light. This radiation is better suited to the 3D-printed lenses, but Ozcan says using visible light instead would be possible with better-quality lenses. A sensor was added at the other end of the lenses.

The AI-designed camera successfully photographed the target numbers, while diffracting away light relating to anything else so that it didn't appear in the photo. Other tests on images of clothing such as trainers and trousers were also successful. The lens designs allow certain shapes from objects to pass, but diffract others so their light never reaches the sensor (*eLight*, doi.org/gqnnqn).

> "I cannot define mathematically what trousers are. That's where deep learning comes in"

Ozcan says the AI creates lenses that would be impossible to design mathematically from scratch. "Basically, it's a puzzle," he says. "I cannot define mathematically what trousers are. That's where deep learning comes in. Mathematically, what this does is difficult to explain."

As the processing is done physically, no image editing is needed by computer. But because the lenses are physical, once made, they will only work for one set of target shapes. ▮

Matthew Sparkes

Engineering

3D-printed wood twists into shape

WOOD shavings have been turned into 3D printer ink to make objects that start off as damp, flat sheets and then twist and warp into shape as they dry. This method could make wood sturdy enough to be used for furniture or parts of buildings in the future.

Wood naturally changes shape as it dries because of the structure and orientation of its cells. Doron Kam at The Hebrew University of Jerusalem in Israel and his colleagues took advantage of this by 3D printing with an ink made primarily of "wood flour" or ground-up leftover wood from construction. They used the technique to create a metre-sized bowl and a spiralling helix.

Kam presented the work at a meeting of the American Chemical Society in Chicago on 23 August.

Karmela Padavic-Callaghan

Technology

Battery charges in under a minute

A FAST-CHARGING and fire-resistant battery made from aluminium and sulphur could be used in electric cars, avoiding the fire hazards linked to lithium-ion batteries.

Donald Sadoway at the Massachusetts Institute of Technology and his colleagues developed the battery, which can charge to full capacity in less than a minute, store energy at similar densities to lithium-ion batteries and isn't prone to catching fire. "This is a totally new battery chemistry," says Sadoway.

Although the battery operates at the comparatively high temperature of 110°C (230°F), it is resistant to fire because it uses an inorganic salt that can't burn as its electrolyte, the material that allows charge to flow inside a battery (*Nature*, doi.org/h869).

Alex Wilkins

IANDAGNALL COMPUTING/ALAMY

Health

Malaria vaccine using live parasites shows promise

AN EXPERIMENTAL malaria vaccine that consists of living parasites weakened by the deletion of three key genes has produced promising results in a small trial involving 16 volunteers.

After a person is bitten by a malaria-infected mosquito, the malaria parasites (*Plasmodium falciparum*) travel to the liver and begin to multiply there. This liver stage causes no symptoms. It is only when the parasites start infecting red blood cells that symptoms appear.

Stefan Kappe at the Seattle Children's Research Institute and his team deleted three genes in the parasite that are essential for it to leave the liver and infect blood cells. These genetically modified parasites can't cause severe disease, nor can they be transmitted to other people. "The parasite can't come out of the liver and cause blood-stage infections," says Kappe.

The team "vaccinated" 16 volunteers by allowing them to be bitten by mosquitoes infected with the modified parasite at least 200 times on three or five occasions.

When the volunteers were later exposed to mosquitoes infected with unmodified parasites, half didn't develop blood-stage infections. By contrast, four out of five unvaccinated volunteers exposed to unmodified parasites developed blood-stage infections (*Science Translational Medicine*, doi.org/gqpxdb).

As the live vaccine has to be delivered by mosquito bites currently, the team is working on ways of breeding parasites outside mosquitoes so they can be injected directly into a person. **Michael Le Page**

Really brief

MADELEINE STEINBACH/AGEFOTOSTOCK/ALAMY

Vegan milks are lower in nutrients

Most plant-based "milks" have lower amounts of four key micronutrients – phosphorus, magnesium, zinc and selenium – than cow's milk, according to research presented at the American Chemical Society meeting in Chicago. Pea milk was an exception, with similar levels to cow's milk.

Dolphin genes affected by oil spill

Dolphins living off the coast of Louisiana during and after the massive Deepwater Horizon oil spill in 2010 show changes in the activity of genes that regulate lung tissue growth and immune responses. These changes could indicate higher risk of future disease (*PLoS One*, doi.org/h86n).

Water made to act like a sponge

Water can be modified to absorb gases in a sponge-like way by adding nanocrystals containing small pores. This enables it to carry 10 times as much oxygen as blood, which could help it to act as an oxygen source in artificial blood substitutes (*Nature*, doi.org/h86p).

Signal Boost

Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **The Mary Rose Trust**

Take a dive into the past

After many years of excavation and tens of thousands of dives, on 11th October 1982, the Mary Rose returned to the surface in one of the most anticipated archaeological events the world has even known – it remains to this day the largest underwater excavation ever undertaken in the world. It was watched by an estimated worldwide audience of some 60 million people and represented the longest outside broadcast and the first underwater broadcast undertaken.

In 2022, we celebrate 40 years since that day, and the work that made it happen. A huge team of divers, archaeologists and scientists was involved - amateurs and professionals alike were dedicated to the cause, with the project breaking new ground in diving and conservation techniques.

Many will remember that day and the crash of the cradle on the hull. But many more may only have memories of visiting as a school child or none at all. The museum which opened in 2013 provides a unique insight into life 500 years ago during the reign of King Henry VIII.

During the 40th anniversary year we will be asking for memories – WhereWereYouin82. Please do contact us via https://maryrose.org/40 with yours.

Many activities and events are being planned to mark this momentous occasion and to celebrate all that was achieved by so many 40 years ago. There will be community engagement projects, a new documentary, anniversary lecture series and a divers' reunion, alongside a multi-sensory experience – 1982: Dive the Mary Rose.

Want to help?

The Mary Rose Trust is an independent charity (no: 277503) and receives no regular Government support. Income from Museum visitors and donations protect the future of the Mary Rose and her amazing story. To find out more or to support the Trust's work please visit maryrose.org.

Do you need your signal boosted?

If you are a charitable organisation working in STEM, science, medicine, technology or conservation, and would like to find out more about this project contact Jacqui McCarron on jacqui.mccarron@newscientist.com

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Comment

A lab the size of a planet

Studying the atmospheres of Venus and Mars can help us understand the human role in climate change on Earth, says **David Grinspoon**

MICHELLE D'URBANO

VENUS and Mars are the closest we will ever come to controlled experiments for Earth. Take three rocky planets, two roughly the same mass, one about one-tenth of that mass. Add water. Make one of the big planets a little closer to your star and the small one a little further out. Now wait 4 billion years and observe.

This is a golden age of comparative planetology. Spacecraft within our solar system, combined with new awareness of exoplanets, are bringing the diversity of planets into focus, which also gives us a new understanding of our home world. As a comparative planetologist, I am particularly fascinated by this local trio of rocky worlds with substantial atmospheres. We can't test our ideas about planetary evolution with laboratory experiments, so we are fortunate to have two close neighbours that have a lot in common with Earth, as well as significant differences.

Our age is fraught because our newly spacefaring civilisation is changing our planet in unplanned ways. An urgent priority today is to understand the human role in climate change. Fortunately, studies of our neighbouring planets can help.

Venus has a nearly pure carbon dioxide atmosphere with a mass almost 100 times greater than Earth's. Historically, attempts to determine the climate of Venus were closely tied to our growing understanding of greenhouse warming on Earth. Now we know Venus is the epitome of an intense atmospheric greenhouse, with a surface temperature of nearly 480°C.

While we aren't close to triggering a Venus-style runaway greenhouse effect on Earth, we are in danger of tipping the balance of our climate away from the safe zone humans have enjoyed for more than 10,000 years. By testing our climate models on Venus, we learn how well they predict conditions far from the present-day circumstances of Earth.

For example, one of the weakest points of our current models is predicting the effects of clouds on future climate. Clouds are tricky because of the complex feedbacks between radiation and the physics of droplets. Depending on the details of a particular cloud, they can either cool or warm a planet. By studying phenomena like the clouds of Venus and their effects on the planet's extreme climate, we push our models to the limit and discover hidden weaknesses. This improves our models for the all-important task of predicting Earth's changing climate.

Mars has the opposite problem. Its atmosphere is also nearly pure CO_2, but lower gravity means most of its air has been lost over time, and what is left is far too thin to have a substantial greenhouse effect. That and its greater distance from the sun have doomed Mars to be a frozen desert. The fact that our models accurately predict the surface climate of the Red Planet provides another extreme test validating our climate tools.

Mars has helped warn us of other potential climate dangers. The theory of nuclear winter was worked out by planetary scientists studying the dramatic Martian global dust storms. They saw what could happen to a planet completely shrouded in dust particles and realised they could apply the same physics to the extreme case of Earth enshrouded in the smoke from nuclear fires. With studies such as these, Earth's sibling worlds become labs for understanding – and circumventing – the dangerous, unintended consequences of our increasingly powerful technology.

Let us hope that, helped by the knowledge we are getting from studying our closest planetary neighbours and the perspective space exploration provides, we can also gain the wisdom to avoid precipitating future disasters and learn how to sustain the unique biosphere of our home world. ▮

David Grinspoon is senior scientist at the Planetary Science Institute in Arizona. He will be appearing at the sixth Starmus Festival in Armenia

Field notes from space-time

Welcome to my TED talk

Giving a TED talk wasn't easy, but I wanted to make sure my audience came away with a better understanding of dark matter, writes **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

Chanda's week

What I'm reading

The powerful Haiti earthquake novel What Storm, What Thunder *by novelist Myriam Chancy.*

What I'm watching

I have been enjoying the cartoon Solar Opposites.

What I'm working on

I am trying to mentally work out what it means to take a vacation!

This column appears monthly

TED talks are increasingly ubiquitous in pop culture. TED's motto is "ideas worth spreading" and it has become famous for accessible, pristinely produced 10 to 15-minute presentations on big ideas.

Of course, this makes them a prime target for satire. Sometimes this will take the form of a short, tweeted statement, such as "Black cats are the best cats!", followed by the note: "Thank you for coming to my TED talk!" I have definitely been an active participant in this satirical TED talk discourse. But I am not sure I ever will be again, because I spent the first third of 2022 preparing a real TED talk and learned that giving one is actually really hard!

My talk was in April, but preparation for it began in December, when I had to formulate my big idea and begin developing a script. In the run-up to the talk, I was practising six or seven times a day to ensure I could deliver the memorised 15-minute monologue without pauses or mistakes. I had the added complication of needing to be careful about how I moved my head because of the design of the TED microphone, which is most ideal for people with short hair and no earrings.

A major part of the challenge wasn't the actual performance, but making sure that what I said wouldn't leave the audience behind. Of course, I was giving a talk about dark matter. My time as a public communicator – and especially the year I spent touring with my book – has taught me a lot about how often people come to discussions about dark matter with pre-conceived notions of their ability to understand what is being said. A lot of people have heard that they aren't good at mathematics from their teachers, or their exam performance indicated to them that they don't have a mind for science.

I generally think that is hogwash, but an audience who don't know me won't be aware ahead of time that my goal is to welcome them into science. Even when people do know me, they still need to overcome their internal bias against their ability to understand. So I tried a variety of ways to help the TED audience take in the questions at hand.

> "People often come to talks about dark matter with pre-conceived notions of their own ability to understand"

For example, I really wanted to emphasise that "dark matter" is something of a misnomer. The word "dark" implies that there is a colour or some other kind of relationship with light. But so far everything we know about dark matter suggests that it simply doesn't interact with light at all, and only interacts with visible matter through gravity. If it really is a particle, light goes right through clumps of it.

The only scenario where dark matter might actually be dark is if it is comprised of small black holes. This is a possibility that scientists are taking seriously in the aftermath of the direct detection of gravitational waves – little ripples in space-time caused by gravitational interactions of extremely massive objects like black holes and neutron stars.

But I am an advocate for the particle scenario, which is the most popular and, in my opinion, the most realistic paradigm. To help people think about what it would mean for the particle to have no interaction with light – to be invisible – at one point in my talk, I stopped, held out my hands and said: "If you put out your hands and think about the weight of having a clump of dark matter in your hands – that's how it would feel, but your hands would look exactly the same."

With my hands cupped in front of the audience, I bounced them a little to make them think about the sensation of holding something weighted. I am fond of this example because it is something almost anyone can do and it almost feels intuitive.

This led to a question from an intrepid Twitter user who watched the talk online. In the scenario where dark matter doesn't interact with everyday matter except for gravitationally, doesn't that mean it isn't possible to hold a clump in your hands? The clump would go right through them, surely?

This is a delightful question that also made me cringe a little bit because it highlighted the limit of my thought experiment. First, it is unlikely that we would be able to gather a clump of dark matter because the density is extremely low: think one particle per coffee mug. Second, if it is true that dark matter doesn't really interact with atoms via the nuclear or electromagnetic forces, it would go right through our hands.

So, confession: you will probably never be able to hold a clump of dark matter in your hands, even if we do figure out what it is. But whether it is completely impossible or not will ultimately depend on the specific properties of the dark matter particle, and whether it truly has no interactions with everyday matter. It might – and that tantalising possibility is one reason I keep trying to understand what exactly dark matter is. ▮

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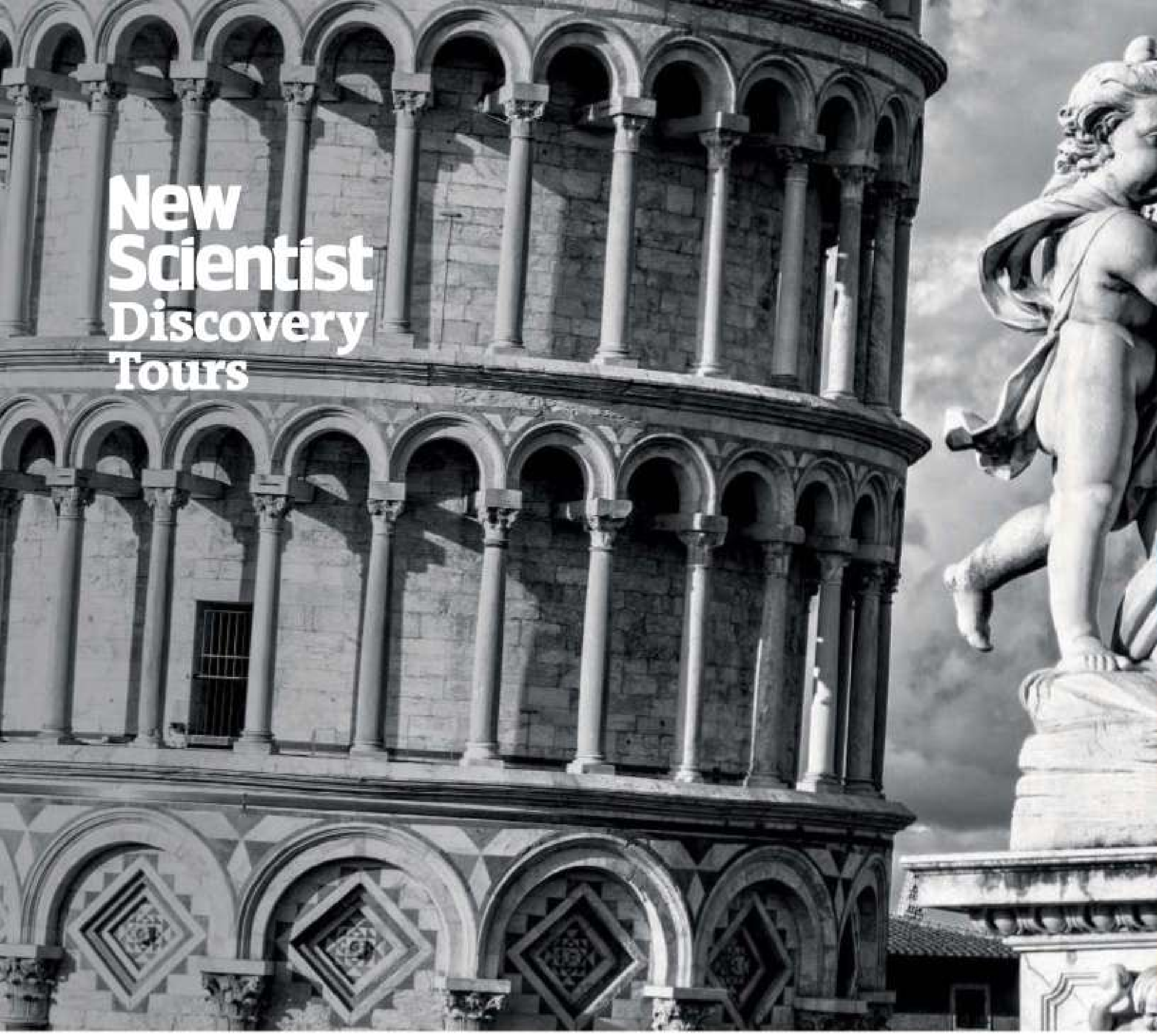
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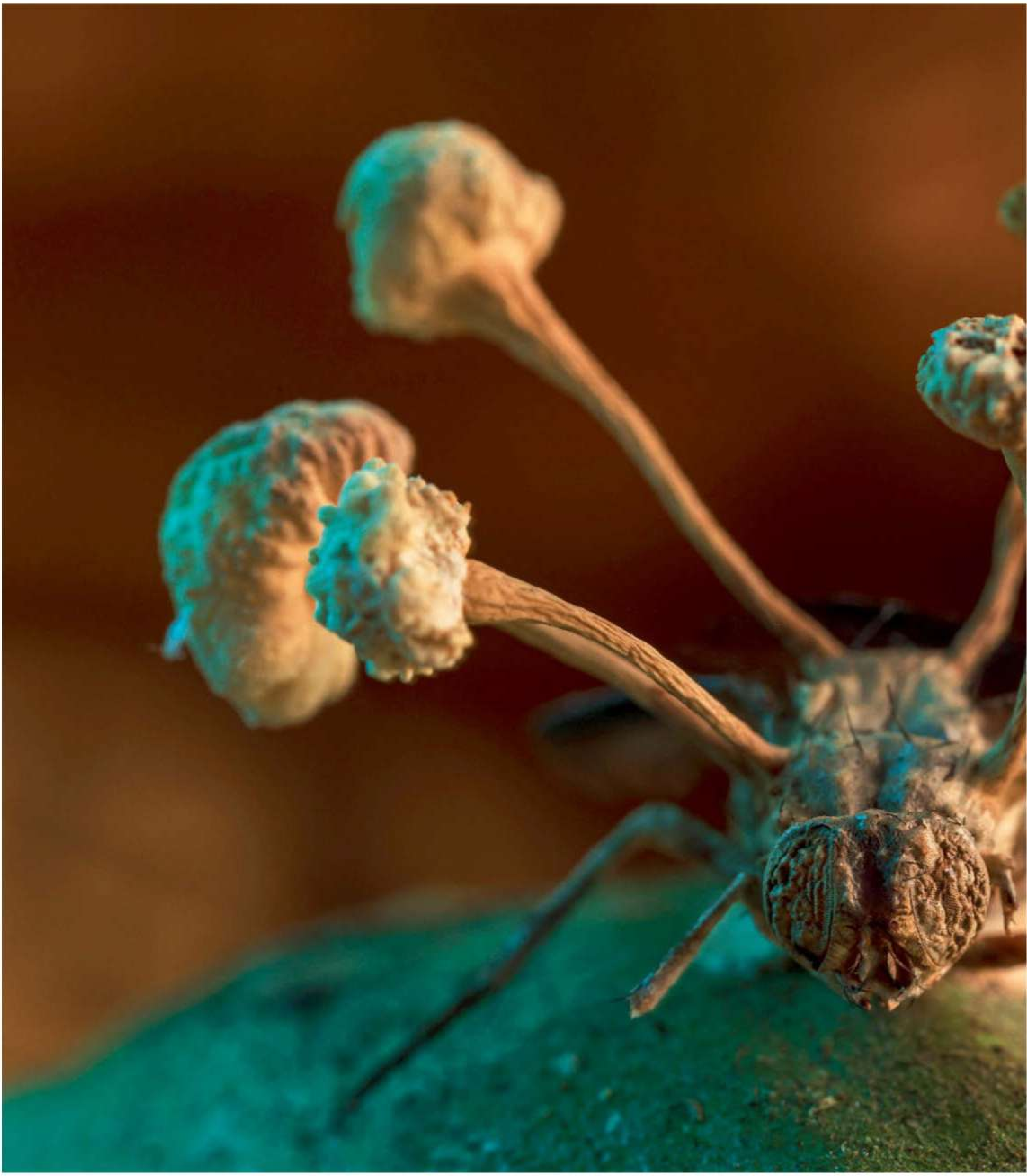

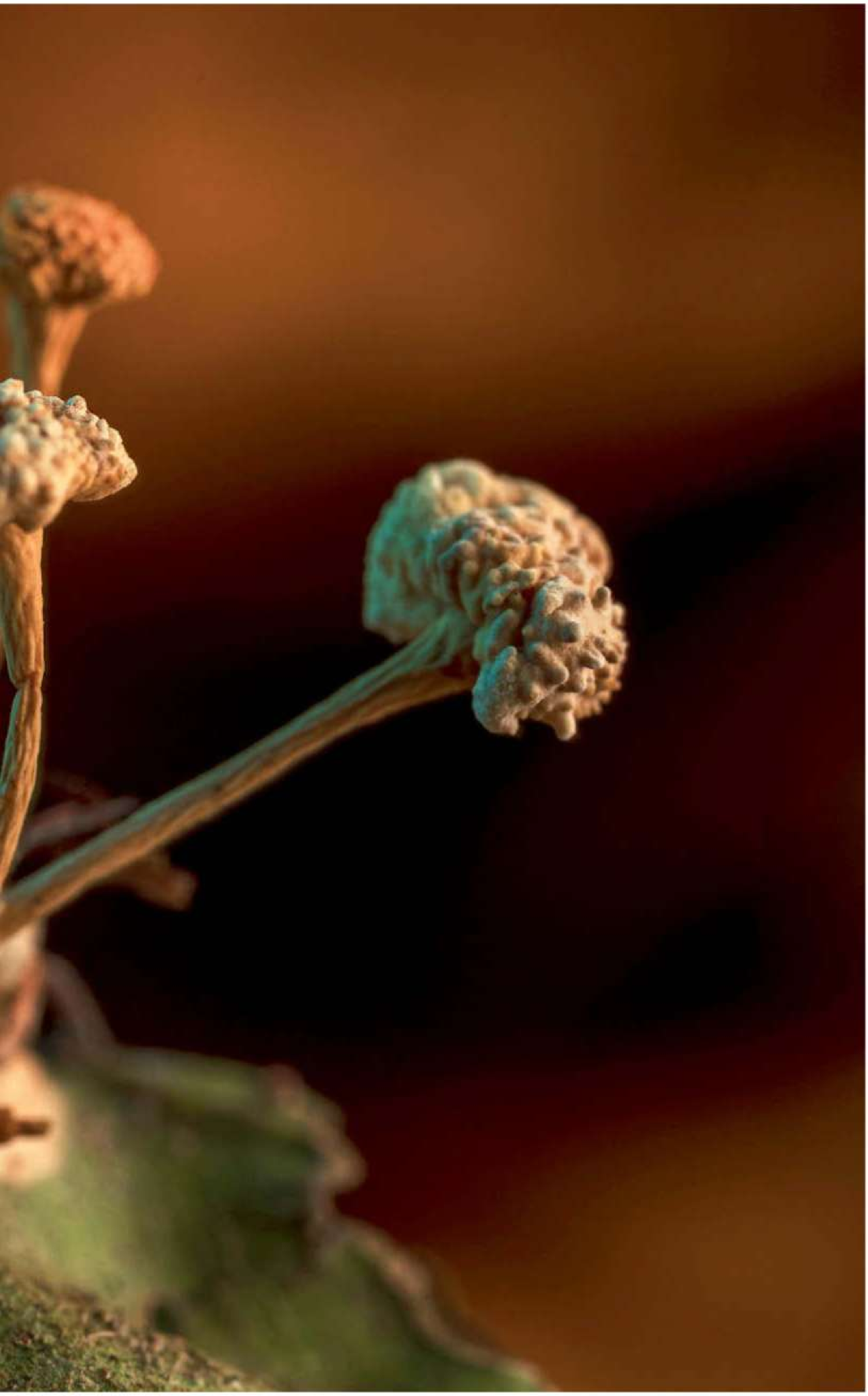

The living dead

Photographer **Roberto García Roa**

THIS striking image looks like the stuff of nightmares – and it isn't far off. It shows the fruiting bodies of a parasitic fungus bursting through the body of a fly, a deadly conquest that has been honed by evolution.

This dramatic and highly disturbing sight was captured by evolutionary biologist and photographer Roberto García Roa at the University of Valencia, Spain, and won him the top prize in the *BMC Ecology and Evolution* image competition.

Also known as zombie fungi, most species in this family are parasites that use their spores to control the minds of insects, such as flies and ants. The bodies of these creatures are then used to spread the fungus and infect more organisms, even other fungi.

García Roa came across the infected insect while trekking in Peru's Tambopata National Reserve. The fungus was able to infiltrate the exoskeleton and mind of the fly, then compelled the insect to move to a more favourable spot for the fungus's growth, said García Roa, in an announcement about his winning image. "The fruiting bodies have then erupted from the fly's body and will be jettisoned in order to infect more victims," he said.

Other species of zombie fungi, such as *Ophiocordyceps unilateralis*, are able to alter the behaviour of ants so that they leave their trails and attach to the undersides of leaves, their heads becoming vessels for the fungus's spores.

Gege Li

Editor's pick

Another way to use this new drilling technique?

13 August, p 25

From Alexander Dunn, Edinburgh, UK

I was fascinated by Eugene Linden's article about deep drilling using millimetre-wave beams. Whenever geothermal energy gets mentioned, it is usually about electricity generation. But there is a simpler way. That is to drill to around 100 metres and bring up hot water for district heating. This could be done anywhere, not just at power station sites.

The new drilling technique Linden mentions also begs the question, could it be used for tunnelling and quarrying? It would be a game changer if explosives were no longer needed for these purposes.

Young moon may have had big influence on early Earth

13 August, p 46

From Jeff Blyth, Brighton, UK

On the discussion about how much land might have been available in Earth's infancy and how this may have affected whether life began on land rather than in the sea, I was surprised that no mention was made of the fact that the moon was much closer to Earth back then.

In addition, Earth was spinning faster at that point, so the days were shorter and the tidal effects on exposed land every few hours must have been huge.

A retreat into silence is impossible for some of us

13 August, p 38

From Gillian Peall, Macclesfield, Cheshire, UK

Kayt Sukel writes that even short periods of near-total silence are good for well-being. But those of us who have tinnitus carry our noise with us at all times. Refreshment of our inner self can be harder to come by.

Now is the time to step up the climate message

6 August, p 29

From Bruce Denness, Niton, Isle of Wight, UK

Bill McGuire recognises that the problem with demonstrating the urgent need to control global warming is no longer scientific – it is a matter of public and political understanding and acceptance. For instance, faced with current cost-of-living problems, a typical reaction from some members of the public and politicians is to advocate scrapping the pursuit of net-zero emissions.

Sadly, this response is to blame for continuing inaction on controlling the greenhouse effect, and can only be overcome, as McGuire says, with a massive public information campaign.

Having run their global warming marathon, scientists mustn't collapse in despair at ignorance within sight of the winning post. They must instead dress their message in the catchy phrases of the popular press.

How can this dose of radiation be justified?

6 August, p 22

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

On the possible use of dental X-rays to assess the age of asylum seekers, I was professionally involved with UK ionising radiation regulations more than 30 years ago, and I recall it was advised that doses be kept as low as reasonably achievable. Also, I believe that every exposure needed to be medically justified in terms of benefit to the recipient – this being especially emphasised for children and young adults.

I realise that rules have probably changed, but it is hard to believe that such fundamental principles have been abandoned. I can't therefore understand how such an obviously political decision to expose asylum seekers, possibly children, to X-ray doses could ever be justified.

Many ways to hack an unconnected computer

6 August, p 22

From Sam Edge, Ringwood, Hampshire, UK

The use of Serial Advanced Technology Attachment (SATA) cables in computers to transmit data at radio frequencies so it can be purloined is interesting. However, there are other ways to extract data from computers that aren't connected to the internet.

There is, for example, a proof-of-concept malware that modulates the fan speed of computers to send information to a concealed microphone or compromised smartphone. The data is sent in sound waves, albeit at a low rate.

We have no choice but to embrace gene-edited crops

16 July, p 20

From Geoff Harding, Sydney, Australia

Gene editing aimed at greatly increasing the yield of wheat and other staple crops should be pursued with haste, both to improve food security and to free up suitable farmland for reforestation.

There will inevitably be some resistance to gene-edited food, but the increasingly serious problem of food insecurity, and the need to tackle climate change with a wide raft of solutions, must convince consumers that there is little choice.

Make that six numbers to describe the universe

13 August, p 42

From Susan Payne, Cape Elizabeth, Maine, US

How cool is it that your article about five numbers that transform our understanding of the universe started on page 42, the number made famous by *The Hitchhiker's Guide to the Galaxy* as the answer to life, the universe and everything?

Inquiring minds are keen to know whether this was by chance, perhaps guided by an unseen hand, or whether it was an editor's tip of the hat to Douglas Adams?

Love of waterside life could be a survival thing

Letters, 13 August

From Austin Davis, Swadlincote, Derbyshire, UK

After reading the letters inspired by your feature "Into the Blue", I have been pondering how proximity to water can have a calming effect.

Is it possible this is because of a psychological response that motivates us to be near to water, which is necessary for our survival? This would be much like how the taste of sugar is pleasing, and so encourages us to consume energy-rich fruit in a natural transaction with plants that provides us with sustenance in exchange for dispersing their seeds.

Perhaps, as fresh water is tasteless and odourless – meaning it may not be possible for it to act as a chemical stimulus – we have instead evolved to have a positive psychological response to the sight and sound of it.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT will be delayed

For the record

It was teenagers with existing mental health problems who were affected by mindfulness lessons in UK schools, not teenagers generally (20 August, p 25).

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BEING HUMAN SERIES
CAMILLA PANG

When plants play detective

From a marijuana database to the possible poisoning of the Buddha, this book tells the story of plants' complex role in crime, says **Kate Douglas**

Book

Planting Clues: How plants solve crimes

David J. Gibson

Oxford University Press

MLADENBALINOVAC/GETTY IMAGES

Forensic botany can be a key witness in cases of murder or rape

THEY called him the Sherlock Holmes of France – and, in fact, his antics did inspire the novelist Arthur Conan Doyle.

When Edmond Locard established his forensic science lab in 1912, the world had never seen anything like it. The place wasn't much to look at – cramped quarters on the fourth floor of the Palais de Justice in Lyon – but there Locard set about laying the foundations of a completely new scientific discipline.

As befits the time, his methods involved self-experimentation, including a study to find out whether fingerprints can be burned off. They can't. He also spent years examining "dust" – microscopic detritus ranging from bacteria to sloughed-off bits of human. But it was his scrutiny of plant fragments that really put him ahead of his time.

Fast-forward a century and forensic botany is still in its infancy, as David J. Gibson makes clear in *Planting Clues.* In addition to Locard, we meet other pioneers of this rapidly developing science, including Jane Bock, a plant anatomist who was phoned out of the blue one day in 1982 by a coroner who wanted to know whether it was possible to deduce the last meal of a dead woman from the contents of her stomach.

Bock and her colleague David Norris set about chewing food samples 32 times – just like your grandmother told you to – spitting them out and then examining the gloop under a microscope. All that chewing paid off and their evidence helped to solve the case.

Another groundbreaker was Tim Helentjaris. In 1993, while working as a plant geneticist at the University of Arizona, he showed that DNA extracted from seed pods discovered in a suspect's truck matched a blue palo verde tree at the site where a body had been found. The case was the first time that genetic evidence from a plant had been admitted in court.

Planting Clues contains many tales like these, where forensic botany is a key witness in cases of murder or rape. They can make for uncomfortable reading. Besides, if you are a regular watcher of crime dramas like *CSI* or *Silent Witness*, you are probably already aware of the ways in which plant materials can link suspects with victims and/or the scene of a crime.

But there is so much more here. Gibson recounts the case of Delgamuukw v British Columbia, in which microscopic pollen was used to support a land claim based on oral history made by the Gitxsan and Wet'suwet'en people in British Columbia, Canada.

He goes on to describe a marijuana database that contains DNA from 3000 varieties of cannabis and hemp, provides 3D interactive maps showing their evolutionary relationships and can even offer the flavour profile and pedigree of a particular plant.

> **"The Western diet contains only 70 plants – helpful for working out what someone last ate"**

Gibson also tells us that humans eat just 3000 of the 400,000 known plant species, with the typical Western diet containing only 70 or so – which is a very helpful fact if you are trying to work out which vegetables someone ate before they died.

His writing is fascinatingly horrible when it comes to describing rotting human corpses, with details that might escape even the most thorough and up-to-date TV series. First, the body releases caustic, plant-killing fluids, then it adds around 2.6 kilograms of nitrogen fertiliser to the soil. Gibson calls the result a "cadaver decomposition island", consisting of a plant-free area surrounded by lush vegetation.

Chapter 6, entitled "A forensic pharmacopoeia", is even more intriguing. Do you know how many fly agaric mushrooms it takes to kill a healthy adult? And did you know that famous fungal homicides may include the death of Siddhartha Gautama, who was known as the Buddha? Or that atropine, a toxin produced by deadly nightshade, can be used as an antidote in some cases of mushroom poisoning?

Of course, fungi aren't plants. But by including them in this wide-ranging survey of forensic botany, Gibson shows just how much the natural world is involved in our human interactions, for good or ill. ■

A future for climate refugees?

Helping those displaced by a warming world means rethinking human identity, argues a bold new book. **James McConnachie** explores

Book
Nomad Century
Gaia Vince
Allen Lane

GAIA VINCE is something of a star in climate science writing. Her debut, *Adventures in the Anthropocene*, was a compelling blend of climate science reporting and travelogue. *Transcendence*, her second book, sought to explain human evolution in ambitious "big history" terms – think Yuval Noah Harari meets Matt Ridley.

Her latest, *Nomad Century: How to survive the climate upheaval*, offers more big history, though it tackles the future. Vince predicts a world where a changing climate will transform the distribution of Earth's population within the lifetimes of her children. A rise of 4°C by 2100, she argues, is "somewhere between definitely possible and reasonably likely" – certainly, she says, "likely enough to plan for".

Vince's focus isn't on climate change, though, but on how people will respond to it. Drawing on research, think-tank studies and a fair few assumptions, many of them reasonable, she warns that average heating of between 3°C and 4°C would trigger the creation of billions of climate refugees.

She tries to reframe this as a positive. Migration has been the source of humanity's success in the past, she argues; a "nomadic soul" apparently "perches inside us all". Migration will also benefit the economies of the countries of destination and, through remittances, those of origin.

To succeed, we just need to acquire a "pan-species identity" – and to organise, says Vince. She envisions a UN body that will compulsorily purchase vast areas of land in Russia, Canada and Scandinavia, build prefab megacities and compel states to accept set numbers of migrants, who will undertake (voluntarily?) a form of national service and become citizens of the UN.

She suggests that China's control of internal migration by means of its hukou system could be a model. She admits this was "controversial" but, in her view, it has shown that it is "possible to create large migrant cities rapidly" while avoiding the creation of large slums.

There is nothing wrong with having a plan, but it seems people will have to abandon a fair amount of their democratic freedoms to adopt Vince's. What's more any plan has to be built on solid foundations, and some of the underpinnings here look a bit wobbly.

Vince asserts, for instance, that the collapse of multiple Bronze Age civilisations 3200 years ago was the result of "climate chaos" and drought. This striking hypothesis has been put forward in recent years, but it is far from established. To pick another example, also from a hypothesis awaiting more evidence: did an individual's nationality really have "little political meaning" before the end of the 18th century?

In details such as these, as well as in her overall vision of the future, Vince's approach can seem too broad-brush and too sure. Climate scientists have learned, painfully, to be careful about communicating uncertainty. But then this is only partly a science book: it is more of a futurist vision yoked to Vince's own manifesto, which advocates tightly controlled migration, geoengineering and if not global government, then unprecedentedly close global cooperation.

Vince is aiming for compassionate realism, but some of her proposals could play into the hands of those who say that the "green agenda" is a Trojan horse for totalitarianism. I suspect Vince would say that she is just provoking thought and debate, and this she absolutely does.

Climate refugees are on the move already. The question, she says, "is whether they will be helped, or whether the rest of the world will stand by and watch them die". ▮

James McConnachie is a writer and editor based in Hampshire, UK

Megacities in the near future could be built on vast swathes of Russia, Canada and Scandinavia

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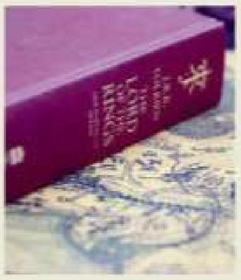

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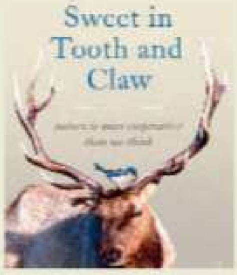

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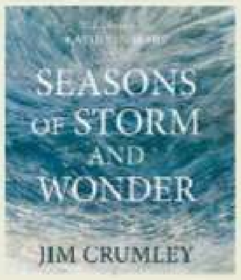
Sweet in Tooth and Claw is a new attempt to rebalance our view of evolution. Author Kristin Ohlson argues that, despite appearances, cooperation plays as big a role in survival and adaptation as competition. On sale from 8 September.



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Seasons of Storm and Wonder by nature writer Jim Crumley explores the impact that climate change has had on the Scottish Highlands since he first began observing his surroundings. On sale from 8 September.

TOP: AST FREELANCER/ALAMY

The film column

Taking direction Five people in recovery from psychosis guide artist Marcus Coates as he recreates aspects of their experience in this series of disorienting and sometimes very frightening short films, finds **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram @simon_ings

Film

The Directors

Five short films by Marcus Coates

At venues in London from 4 September to 30 October

ARTANGEL/MARCUS COATES

Recreating experiences of psychosis leads Marcus Coates to dark places

IN A flat in a social housing block in London's Pimlico, artist Marcus Coates is being variously nudged, bullied and shocked out of his sense of what is real.

Controlling the process is Lucy Dempster, a teenager in recovery from psychosis. In his ear, Coates hears Dempster prompt him in how to behave, when to sit, what to touch and what to think about. Sometimes, Coates asks for guidance, but more often Dempster's reply is drowned out by a second voice, chilling, over-loud, warning him not to ask so many questions.

A cardboard cut-out appears by his bed: a clown girl with bleeding feet. It is a life-size blow-up of a sketch Coates was told to draw a moment before. He hears a balloon burst, shockingly loud, nearly knocking him over.

Commissioned by Artangel, *The Directors* is a series of five short films, each directed by someone in recovery from psychosis. In each, the director guides Coates as he recreates, as best he can, aspects of their experience. These aren't rehearsed performances: Coates receives instructions in real time through an ear-piece. (That this evokes the auditory hallucinations often experienced with psychosis is a coincidence lost on no one.)

So: some questions. In the course of each disorientating, sometimes very frightening film, does Coates ever experience psychosis? And does that matter?

> **"Coates's work champions the vexed, imperfect business of imagining our way into other heads"**

Coates's work champions the imperfect, necessary business of imagining our way into other heads, human and non-human. 2007's *Dawn Chorus* revealed common ground between human and bird vocalisation. He slowed recordings of birdsong down 20-fold, had people learn the slowed-down songs, filmed them, then sped the films up again. The result is a charming, startling glimpse of what humans might sound like if brought up to "bird speed".

In 2010's *The Trip*, as part of a collaboration between the Serpentine Gallery and St. John's Hospice in London, Coates enacted the unfulfilled dream of an anthropologist called Alex H. Journeying to the Amazon, he followed precise instructions so that the dying man could conduct, by a sort of remote control, his unrealised last field trip.

The Directors is a work in that spirit. Inspired by a 2017 residency at the psychosis unit of Maudsley Hospital in London, Coates's effort to embody and express the breadth and complexity of psychosis is, in part, a learning experience. The project's extensive advisory group includes Isabel Valli, a neuroscientist at King's College London with a particular expertise in psychosis.

In the end, though, Coates is thrown back on his own resources, having to imagine his way into a condition that, in Dempster's experience, robbed her of any certainty in the perceived world, leaving her emotions free to spiral into mistrust, fear and horror.

Dempster's film is being screened in the bedroom where her film was shot. The other films are screened in nearby locations, including one in the Churchill Gardens estate's 30-seater cinema. Arguably the most claustrophobic and frightening of the lot, this film finds Coates drenched in ice water and toasted by electric bar heaters in an attempt to simulate the tactile hallucinations that psychosis can trigger.

Asked by the producers whether he found the exercise in any way exploitative, its director, Marcus Gordon, said: "Well, there's no doubt I've exploited the artist." ▮

Simon also recommends...

Film

Bigger Than Life (1956)

Who says we didn't talk about mental health in the 1950s? Nicholas Ray's superb fact-based drama stars James Mason as a family man driven to the edge by cortisone treatments.

Book

Desperate Remedies

Andrew Scull

Allen Lane

This impassioned history of psychiatry reveals why the field has spent 200 years bringing only marginal relief to the mind in crisis.

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Taming the menopause

Hormone replacement therapy has garnered a bad reputation, but it might be time to rethink our relationship with the drugs – and the menopause itself. **Caroline Williams** reports

THE mood swings I could handle. Ditto the night sweats, irregular periods and a libido that swung between randy teenager and old maid. Then the menopause came for my brain and enough was enough. If ageing "naturally" meant giving up the job I love because I could no longer think, I was out. Bring on the hormone replacement therapy.

Within weeks, I found energy reserves that I had forgotten I had. The urge to crawl into bed mid morning disappeared and was replaced with a clear head and renewed zest for life.

It was quite the transformation. So much so that one of the first things I wanted to do with my new mental clarity was to dig in to the science behind what was happening to me. Was I experiencing an age-related hormonal deficiency that I had, sensibly, nipped in the bud? Or was I guilty of jumping on the latest well-being bandwagon, making a big fuss about a natural life stage that would soon pass? And, importantly, am I protecting my long-term health by taking HRT or risking it?

These are questions that scientists have been grappling with for more than 80 years, ever since the first HRT was approved by the US Food and Drug Administration. Premarin, made from oestrogens extracted from the urine of pregnant horses, was licensed in the early 1940s for the treatment of hot flushes and night sweats, the most common menopausal symptoms. There are many others, ranging from heart palpitations and joint pain to brain fog, anxiety and depression.

These symptoms are eminently treatable with HRT. Yet its use has been controversial ever since 2002, when a large, randomised, controlled trial of HRT was stopped after early data suggested the combined oestrogen and progesterone treatment may be associated with an increased risk of breast cancer, heart attacks and stroke. The Million Women Study, published the following year, concluded that HRT had accounted for 20,000 more breast cancer cases in a decade.

The media storm that followed persuaded millions of people in the midst of menopause to bin their prescriptions and made doctors reluctant to write new ones. HRT uptake crashed by half over the next five years the world over and remains low to this day. While an estimated 75 per cent of people who go through the menopause actually experience symptoms, only around 14 per cent take HRT in the UK, says Louise Newson at Newson Health in Stratford-upon-Avon, UK, who is a family doctor and menopause specialist.

Hormone roller coaster

This would be understandable if the scare stories were justified, but in the years since, both studies' methods have been called into question and new research has put the risks into context by comparing them with other lifestyle factors, such as alcohol intake and obesity. But the question of whether to use HRT is about more than just statistics. It is wrapped up in wider social debates about the over or under-medicalisation of "women's problems", in which, as gynaecology researcher Martha Hickey at the University of Melbourne in Australia puts it, "everyone is taking the feminist high ground". It is no wonder we are so confused.

Part of the reason for the confusion is that while menopause marks the end of fertility, the loss of oestrogen it brings has repercussions that go far beyond reproduction. In the run-up to age-related menopause, which is counted as a year after the last menstrual period, the body goes on a hormonal roller coaster, as the ovaries start to run out of the egg follicles that release oestrogen and become less responsive to other hormones that stimulate ovulation. This is perimenopause. It is at this stage, when periods may still be going strong, that those affected may start to experience a bewildering range of symptoms. In people who have their ovaries surgically removed and are thrown directly into menopause, symptoms can appear overnight.

In age-related menopause, not everyone experiences severe symptoms, or indeed any at all. According to the British Menopause Society, 25 per cent of people who experience symptoms of the menopause describe them as severe. But Hickey says that this isn't universal. Across Africa and Asia, there is huge variation in the experiences that people report.

The reason for this variation isn't clear, but there is no doubt that the menopause can be debilitating. Now, a growing number of researchers and campaigners are demanding a fresh look at how we should deal with it.

Some see menopausal symptoms as a kind of biological cry for help. That is because, outside of its role in reproduction, oestrogen has a hand in many other important processes in the body, from maintaining the structure of bones and skin to regulating cholesterol and blood sugar levels. It also contributes to blood vessel flexibility, the growth and maintenance of connections in the brain and glucose ›

ANGUS GREIG

Hormone-free helpers

Are there any evidence-based alternatives to hormonal replacement therapy for the menopause? According to a recent meta-analysis, there is evidence in favour of some plant-based supplements. Several studies suggest that isopropanol, an extract from the black cohosh plant, can reduce hot flushes and night sweats compared with a placebo – although its mechanisms are unclear.

Soya extracts, which act in a similar way to oestrogen in the body, also show promise. More than 30 milligrams per day of the soya plant-derived compound genistein was effective for reducing hot flushes, although researchers warn that the effects take at least 12 weeks to reach half of their maximum effect (compared with three weeks for traditional hormone replacement therapy). There is also some evidence that the effect of soya extracts is dependent on the make up of the gut microbiome.

Such compounds can also help when taken as part of a healthy diet. A recent study showed that a low-fat vegan diet, including 86 grams of soya beans per day, reduced hot flushes by 79 per cent in post-menopausal women. Exercise has also been shown to reduce the frequency of hot flushes.

To help protect bone health, a combination of 400 to 600 international units of vitamin D per day and between 1200 and 2500 mg of calcium is recommended by the North American Menopause Society during perimenopause and menopause. This, combined with regular weight-bearing exercise, reduces the risk of osteoporosis.

Finally, reframing the experience can help. A study by Myra Hunter and Joseph Chilcot at King's College London has shown that cognitive behavioural therapy reduces the impact of symptoms and improves sleep and quality of life.

metabolism in the brain. It is this last function that most concerns Roberta Brinton at the University of Arizona in Tucson.

Brinton points out that most of the symptoms of perimenopause are, in fact, neurological: hot flushes are the result of temperature regulation changes in the hypothalamus; sleep is governed by the suprachiasmatic nucleus; and mood and memory changes are largely related to the brain. Brinton's research shows that oestrogen helps to regulate glucose metabolism throughout the brain, with receptors for the hormone found everywhere, from regions that support memory to those that specialise in emotional regulation. In mice, a lack of oestrogen seriously dents their brains' ability to make energy, leading to a 15 to 25 per cent drop in chemical activity in their brains.

Could this be behind the fatigue and mental fogginess that sent me to the doctor? Brinton thinks it is a possibility. She says that cognitive symptoms could be the result of a brain that is struggling to function.

Brinton's research suggests that if oestrogen isn't replaced, the brain does eventually adapt, but at a cost. With less glucose being metabolised, the brain turns to fats for energy, one easy source of which is the brain's own white matter, the myelin sheaths that insulate nerve cells and speed up processing across the brain. Her research with Lisa Mosconi at Cornell University in Ithaca, New York, has led them to suggest that this could contribute to some of the pathologies seen in Alzheimer's disease.

When asked whether this means anyone with cognitive symptoms should take HRT to protect the brain from long-term damage, Brinton says it is a matter of personal choice, but she believes that toughing it out may not be in our best interests.

This all sounds alarming, but there is disagreement about what these changes in the brain's metabolism actually mean. After all, not every person who goes through the menopause untreated gets dementia.

As for whether HRT helps the brain bypass this metabolic shift to reduce the risks of neurological conditions, Brinton and her team recently published research that suggested it does. They looked at the health of more than 350,000 women who had taken HRT and found HRT reduced the risk of Alzheimer's disease, Parkinson's, multiple sclerosis and motor neurone disease (also known as amyotrophic lateral sclerosis, or ALS) over five years.

But another piece of research, in a similar number of women from the UK Biobank study, suggests that, while spikes in oestrogen levels through adulthood – caused by things such as the use of contraceptive pills or pregnancy – did protect against Alzheimer's disease, the addition of HRT either made no difference or slightly increased the risk of dementia overall.

So far, so confusing. Would the picture be any clearer for the increased risk of breast cancer? Since the 1980s, when taking extra oestrogen alone was shown to increase the risk of endometrial cancer, anyone who takes HRT is usually also prescribed progesterone to counteract the over-thickening of the uterus lining. However, this seems to add slightly to the risk of breast cancer.

To make sense of all this, consider the baseline risk of being diagnosed with breast cancer. According to the British Menopause Society, between the ages of 50 and 55, without HRT, this risk is in the region of 13 in every 1000 women. According to the most recent analyses, adding combined oestrogen and progesterone HRT into the equation increases that risk by an extra 3 to 7 cases per 1000 over five years of use. With oestrogen-only HRT,

the risk is either reduced by 3 in a 1000 or increased by 2 in 1000, depending on which study you look at. John Stevenson, a consultant endocrinologist at the Royal Brompton Hospital in London, points out that the chances of avoiding breast cancer are high, with or without HRT.

In short, HRT slightly increases the risk of being diagnosed with breast cancer. That risk, says Stevenson, is “very small, but it is there and cannot be ignored”.

It should, however, be taken in context with other lifestyle factors that affect breast cancer risk. For instance, consuming 4 to 6 units of alcohol a day adds 8 to 11 additional cases per 1000, while being obese adds 10 cases per 1000, both over five years. Healthy lifestyle choices can reduce risk by the equivalent of a few cases per 1000 over the same period.

Plus, analysis of follow-up data from the 2002 study that caused controversy has shown that despite any increase in cancer risk, there is no increased risk of dying from any cause in the 18-year period after the study was stopped.

Other research backs this up, and analysis of HRT hints at potential protective effects on cardiovascular disease, particularly when started before the age of 60. In addition, a drop in oestrogen increases risk of osteoporosis and HRT has been shown to reduce bone fractures in people who are post-menopausal. Does this mean that everyone going through menopause should take it, regardless of whether or not they have symptoms?

The right balance

Stevenson says no: “For someone who is asymptomatic and at no increased risk for future osteoporosis or cardiovascular disease, then there would be no advantages in taking HRT, only the risks.” Newson thinks differently. “If you were to say, we’ve got this drug that reduces mortality from cardiovascular disease, reduces osteoporosis, reduces clinical depression and it’s really cheap. Everyone would think ‘why aren’t we all having it?’” she says.

One thing that everyone agrees on is that anyone seeking out HRT should be given unbiased, up-to-date information and allowed to make their own decision. This sounds simple, but conveying the complexities isn’t easy. In England, the first official guidelines for GPs only came along in 2015. Even now, says Newson, many people who want HRT are still being refused by their doctors.

Future research will help to further clarify the risks and benefits. A major criticism of many of the studies on which risk assessments are currently made is that they were done in people who were already post-menopausal. Some more recent studies indicate that starting HRT in your mid to late 40s may have a better risk/benefit profile, particularly for cardiovascular disease. Brinton also has preliminary results that suggest early HRT may be good for the brain, too.

The future may also see the advent of targeted hormone and non-hormone-based therapies (see “Hormone-free helpers”, left), designed to bypass particular oestrogen receptors found in the breast while still targeting those in other organs. Brinton sees the future of HRT as moving towards personalised medicine that takes into account a person’s risk factors and treats their symptoms directly. “We really need to bring precision medicine to women’s health, so it’s not either/or, but what works best,” she says.

For now, the best advice for anyone approaching menopause seems to be to weigh up the pros and cons of taking hormones – perhaps even before symptoms start – with your doctor and pick the option that feels least scary. For me, the scariest option is going back to a place where I don’t have the energy to think about it. So, for me at least, HRT is very much worth the risks. ▮

You should consult your doctor before starting medical treatment. Links to studies mentioned can be found in the online version of this article

Caroline Williams is a journalist and author of *Move!: The new science of body over mind*

The other side of the story

The menopause directly affects half of the human population. But what about the other half? Men and some trans women and non-binary people may also see an age-related decline in their dominant sex-related hormone, testosterone. This is linked with changes in mood and strength, as well as a loss of libido, coined the “manopause”.

The difference, though, is that testosterone levels decline very slowly, at the rate of about 1 per cent per year around the age of 40, and only about 1 to 2 per cent of people report symptoms that are directly related to the drop in the hormone. For these people, testosterone replacement therapies may be offered.

For others, the lack of energy and libido that can accompany midlife is difficult to link with the gradual decline in testosterone. Obesity, diabetes and other lifestyle factors like stress, smoking, doing less exercise and alcohol might account for at least some of the symptoms. What’s more, the drop in testosterone isn’t a change that signals the end of these people’s reproductive lives.

In short, a lack of testosterone can cause problems in some people. But it certainly isn’t a version of the menopause.

GILLES & CECILIE

Space oddities

A new telescope is about to start the biggest-ever survey of the night sky, and astronomers are getting ready for an onslaught of weird discoveries. **Stuart Clark** reports

IN 1967, astronomer Jocelyn Bell Burnell was searching the night sky for quasars, super-bright sources of light in the centre of some galaxies, when she spotted something unusual. It was a pulsing radio signal from space that seemed too regular to have a natural source. With her supervisor Antony Hewish, she half-jokingly dubbed it LGM-1 – short for little green men.

After finding more of these signals, they turned out to be coming from pulsars, dense, rapidly rotating stars that send regular bursts of energy our way. No little green men, after all. But the discovery demonstrated that astronomers need an open mind.

Now, this is truer than ever. In July 2023, the Vera C. Rubin Observatory in Chile will start studying the universe. It will scan the entire southern sky in an unbelievably rapid three nights, then start over. For 330 nights a year, over 10 years, Rubin will produce the Legacy Survey of Space and Time (LSST). It will change how we see the universe, especially our view of the mysterious objects that are pulsing, blipping or otherwise changing in unexpected ways.

Such signals are buried in a tapestry of electromagnetic waves that hurtles our way every night. Until now, we could only unpick the most obvious of threads. But armed with Rubin's telescope and the power of artificial intelligence, we will see more detail than ever before. Some of it will help us unravel current mysteries, while other aspects will be entirely unexpected. The next time someone writes "LGM" next to a strange signal, they might not be doing it with their tongue in their cheek.

For a long time, we thought of the universe as a serene – even heavenly – place where hardly anything changes. Stars were as close to eternal as you could get and stood in stark contrast to the fevered comings and goings of humankind. But as telescopes extended our senses, so we began to glimpse the truth. Now we know there is plenty of change out there. We have glimpsed exploding stars called supernovae, the pulsating stellar corpses of pulsars, black holes devouring gas clouds and planets drifting in front of stars. But we know there must be much more that we simply haven't had the ability to see yet because we have never had a telescope like Rubin's before.

Traditionally, telescopes that scan the entire sky, known as all-sky surveys, have taken months or years to do this. The UK Schmidt Telescope at Siding Spring Observatory, Australia, was built in the 1970s to survey the southern skies. It took 13 years to complete its survey, capturing its images on 35-centimetre-wide square glass plates. Since then, there have been many other similar efforts at different wavelengths and with different instruments. In 1990, the Röntgensatellit (ROSAT) spacecraft took six months to complete an all-sky survey of celestial X-ray sources. Now, Rubin will take a matter of days. Never before have astronomers been able to compare the almost day-to-day appearance of so many celestial objects. All-in-all, this represents a coming of age for a discipline called time-domain astronomy, which seeks to understand how celestial objects change with time.

"It is going to be a giant leap," says Mario Jurić, director of the Institute for Data Intensive Research in Astrophysics and Cosmology (DIRAC Institute) at the University of Washington in Seattle, who is a data management project scientist for the LSST. "We're going to see 10 per cent of everything that's in the Milky Way with this one machine." That accounts for around 20 billion stars, and because of Rubin's light-gathering power and speed, it will detect even slight changes in the brightness and position of objects.

"We're going to see 10 million things changing in the sky every night. So, each night, you're going to see a 1 in 10 million event happening," says Jurić. That statistic marks a seismic shift in the very nature of the objects and events that astronomers can investigate, since even rare celestial events will now appear almost every night. That means there are all sorts of previously exotic events that astronomers are hoping Rubin will find in much greater numbers.

> "Each night, you are going to see a 1 in 10 million event happening"

First, there are the fast blue optical transients (FBOTs), which are pretty much what their name implies: fast pulses of blue light. Only five of these have been seen so far. They could be supernovae that are surrounded in dense clouds of dust and gas, which alters the colour of the light they emit. Finding more with Rubin will allow astronomers to make a much better determination of their properties and hopefully reveal their true identities.

Second are the kilonovae. These are top of astronomers' most wanted list. A kilonova is an explosion, one with about a hundredth to a tenth the energy of a typical supernova. Again, astronomers know of only a handful, all detected serendipitously by different instruments. They are thought to be the collision of two dense stellar corpses known as neutron stars, or maybe a neutron star colliding with a black hole. They should be relatively common, but have largely flown under the radar because they fade so quickly.

"A good old-fashioned supernova lasts about a year," says Federica Bianco at the University of Delaware, who is co-chair

›

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of the LSST Transients and Variable Stars collaboration. "A kilonova last weeks, but the really bright emission evolves very rapidly, so you might only have a few days to see it."

With its three-day, all-sky coverage, Rubin is well suited to detecting them. This is particularly exciting because the detection in 2017 of a gravitational wave signal, caused by ripples in space-time, is thought to have been emitted by a kilonova produced by two colliding neutron stars. This was the sixth gravitational wave event detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO), but the first one not to have been produced by the merging of two black holes. Because the LIGO detection was communicated in a speedy fashion, 70 observatories around the world and in space managed to observe the kilonova's aftermath using instruments that span the electromagnetic spectrum, from radio wavelengths to X-rays and gamma rays.

Sorting through chaos

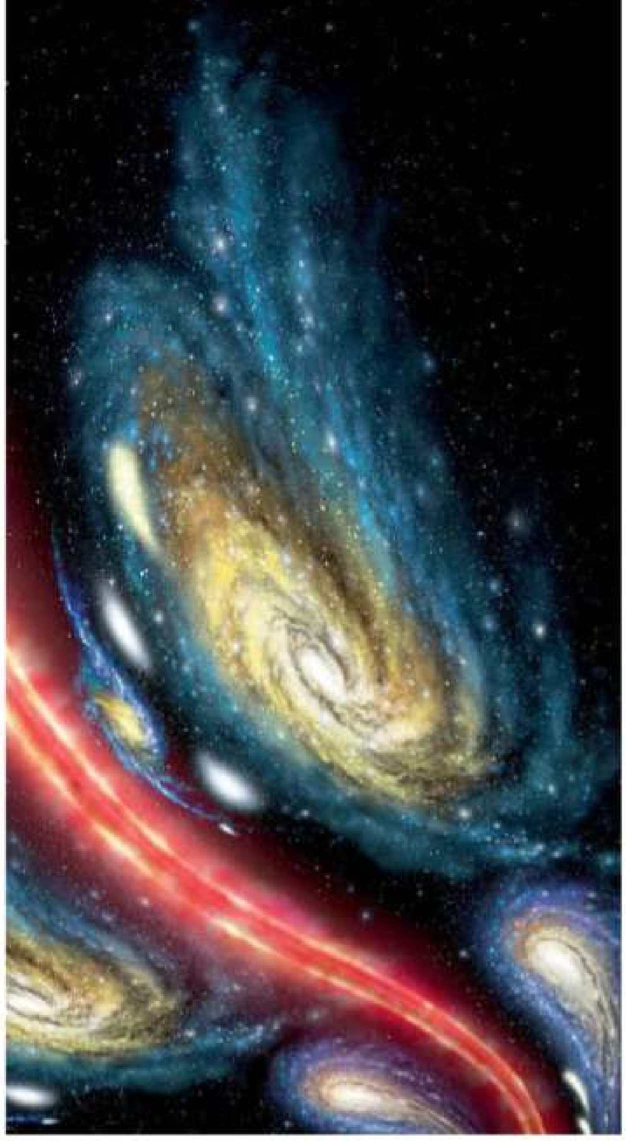
Putting together data from different observational techniques is called multi-messenger astronomy. "This is very much a focus in modern astrophysics," says Bianco, and Rubin will be instrumental in spotting any visible counterparts to future gravitational wave detections. Its surveys will mean astronomers will be awash with information. But first, they have to work out how to drink from the fire hose without drowning.

Not all changes Rubin's telescope spies will be sudden or large, which is what usually triggers an alert for further observations on other instruments. Many celestial objects will be evolving over the course of years or decades. With each object in the LSST being observed between 800 to 1000 times during the first 10 years of the survey (adding up to a nearly continuous set of data for tens of billions of celestial objects), even the slyly shifting ones should show up. The LSST's archive will be a rich source of discoveries in the long run.

The problem is, sifting through that amount of data isn't easy. By any measure – the number of stars observed, the volume of space surveyed, the amount of data to sort through – Rubin is at least 10 times better than anything that has come before. When data starts coming in from July next year, it is probably going to seem like chaos, with signals changing all over the place without rhyme nor reason. Just keeping up with the data flow, let alone sorting through it all, is going to be a Sisyphean task. "None of us working on the project would be able to figure it all out," says Jurić.

> "One of the 'unknown unknowns' we really would like to see is evidence of alien life"

Astronomers hope to find oddities like cosmic strings



LYNETTE COOK/SCIENCE PHOTO LIBRARY

Thankfully, they don't have to. Instead, they have been developing machine learning and artificial intelligence programs to do the heavy lifting. Some of these are already in use, for example at the Zwicky Transient Facility (ZTF). ZTF is a precursor time-domain sky survey that has been used to pave the way for Rubin. It has now been working for three and a half years using instruments at the Palomar Observatory in California. Instead of Rubin's expected 10 million alerts for objects of interest each night, ZTF produces hundreds of thousands per night.

As Rubin's telescope scans the night sky, taking image after image, AI-powered systems look for anything that has changed, creating an automatic alert that is sent to a group of astronomers and observatories around the world dubbed "data brokers". They then distribute the information further so that the discoveries can be prioritised and followed up by other telescopes. Each of the data brokers has different areas of interest. For example, one may be searching for asteroids, while others may look only for supernovae. The same kind of alert stream will be employed by Rubin. Within 60 seconds of an image being taken, software will have identified the changing sources and alerted the data brokers.

As a result, machine learning and advanced statistical methods are emerging as a whole new branch of astrophysics. With the LSST as its focus, thousands of astronomers around the world have gathered into different groups to develop their own complementary algorithms for extracting as much information from the data as possible. The groups include one to find asteroids and other minor bodies in the solar system, one to study powerful, black-hole-fuelled galaxies called active galactic nuclei, a dark energy-mapping group, another tracing the structure of the Milky Way, one interested in explosive objects and more. "There is a big chunk of the community that is getting involved and getting their hands dirty," says Matthew Graham at the California Institute of Technology, project scientist for the ZTF.

The raw data from Rubin's 10-year observations will total around 60 petabytes, or 60 million gigabytes. Combining this in various ways to produce final images and other products that astronomers can then analyse will expand that to around half an exabyte, or about 500 petabytes. The AI routines can then comb through this data, correlating it this way and that, looking for any similar behaviours,

The telescope at Vera C. Rubin Observatory on Chile's Cerro Pachón mountain will start to map the sky in 2023 (left and below)

RUBIN OBS/NSF/AURA; H STOCKEBRAND/RUBIN OBS/NSF/AURA

grouping known objects and phenomena together and then spitting out anything else that seems strange enough for its human masters to investigate. This will undoubtedly reveal a plethora of unanticipated phenomena.

"This is my favourite thing to think about, how can Rubin support and foster the discovery of 'unknown unknowns' or true novelties in the sky," says Bianco. In most cases, it seems certain that to understand these new phenomena, astronomers will need additional observations, probably with other facilities. To understand a new phenomenon or object, you first have to gather as much information about it as you can.

Extraterrestrial signals

One thing that could show up is evidence of exotic cosmological objects, such as cosmic strings. These are hypothetical creases in the fabric of space that would behave like gravitational lenses, producing mirror images of distant galaxies. Finding one would be a gift for cosmologists. The strings are thought to have formed in the early universe as the various forces of nature became distinct from one another and the space-time continuum settled into its current form. Cosmic strings are a bit like the cracks that can appear in blocks of ice as water freezes, so finding and studying one could tell us about the condition of the early universe.

"One of the unknown unknowns that we really would like to see is evidence of alien life, right?" says Bianco. Time-domain astronomy has had a few close brushes with the extraterrestrial already. As well as the discovery of pulsars in the late 1960s, in 2015, the world was gripped by the story of Tabby's star. Tabetha Boyajian at Yale University and her colleagues reported that star KIC 8462852 was undergoing dramatic dips in its brightness. Up to 20 per cent of the star's light was being obscured from view for between five and 80 days at a time over a roughly three-year period.

It was an unprecedented observation, prompting speculation that it might be the result of something an alien civilisation would build. The idea was simple: extraterrestrials would gradually surround their sun with technology designed to capture its light and transform it into electrical power. As this half-built megastructure orbited the star, it would occasionally block out a large fraction of the star's light, giving rise to what astronomers call a "technosignature", an inevitable by-product of an advanced civilisation.

But the apparently random nature of subsequent dimming events convinced astronomers that the most likely explanation for Tabby's star's variability was obscuring clouds of dust that started out dense and then dissipated. It was suggested that the clouds came from a moon that fragmented.

Although the alien hypothesis turned out to be a false alarm, it is exactly the kind of initially inexplicable observation that we should expect to become commonplace with Rubin. Perhaps this time, one of them really will be extraterrestrial in origin. "This question – are we alone? – is fundamental, not only for science and technology, but for philosophy and for society," says Zaza Osmanov at Free University of Tbilisi, Georgia.

Intrigued by the behaviour of proposed megastructures of the sort initially suggested to explain Tabby's star, Osmanov began a series of calculations to determine whether there would be any other observational signatures from them. In 1960, physicist Freeman Dyson showed that such structures should radiate their waste heat as infrared rays to maintain themselves in thermal equilibrium. Osmanov realised a structure in thermal equilibrium is never precisely steady in terms of its radiation output, and will instead oscillate around its equilibrium condition. In the case of a megastructure, this means it could produce a detectable signal that varies with time.

According to his calculations, the oscillation period could be anything from minutes to centuries and could effectively make its host star look like some kind of previously unknown variable star. As such, it could be exactly the kind of weird signal that the machine-learning algorithms are designed to unearth in Rubin's data.

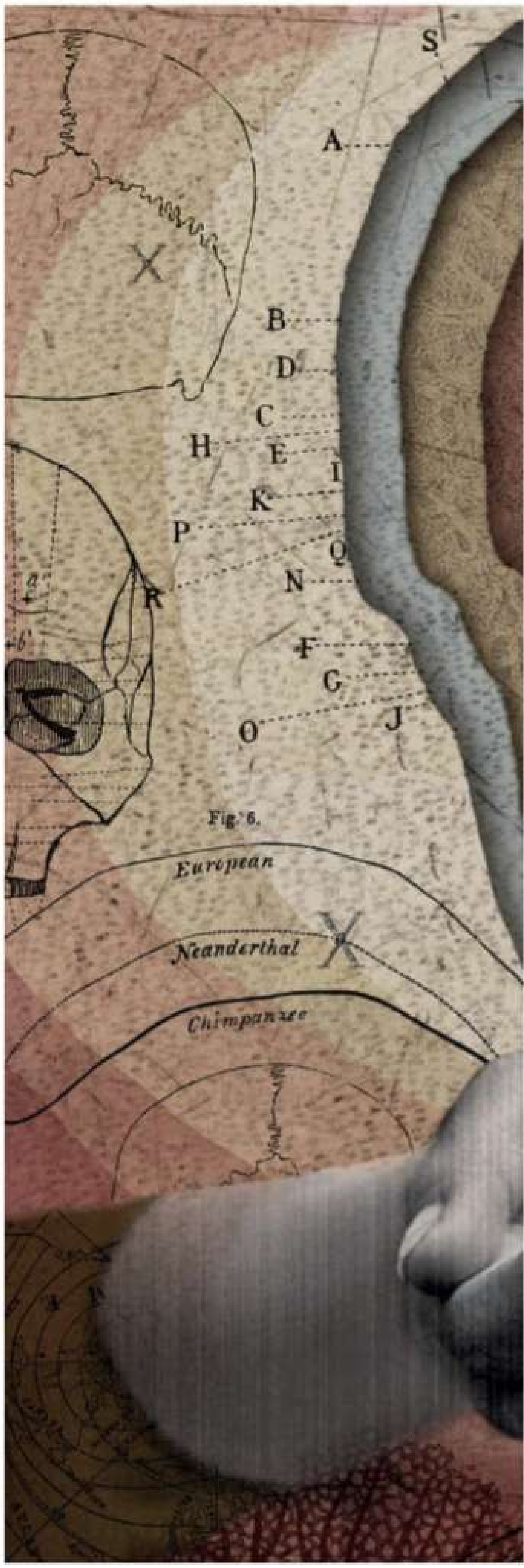
"When it comes to the search for extraterrestrials, that is exactly what you want," says James Davenport, associate director of the DIRAC Institute, "the outliers, the things that do not match any expectations or can't fit with any astrophysical model."

Ultimately, whether it is keeping an eye open for ET or not, there are very few corners of astronomy that Rubin won't progress. By allowing us to access the universe in a way we never have before, it is guaranteed to be transformational. "Any time you look at a new wavelength or a new temporal domain, you can guarantee you will find something you don't understand," says Davenport. "By definition, you're going to find strange things. They may not be aliens, but the likelihood that you're going to find something incredible is almost 100 per cent." ■

Stuart Clark is a consultant for *New Scientist*. His latest book is *Beneath the Night* (Faber)

The search for Ancestor X

The identity of the species that gave rise to all humanity is one of the biggest mysteries in human evolution. **Colin Barras** joins the hunt



MARTIN O'NEILL

THE year is 1933, and China is partly under the control of invading Japanese forces. During construction of a bridge near Harbin in the north-east, a local man working for the Japanese makes a stunning discovery: an ancient human skull. He recognises the skull's value right away. Determined not to hand the fossil over to the occupiers, he buries it in an abandoned well.

There the skull remained until 2018, when, shortly before his death, the man told his family of its existence. In due course, the Harbin skull came into scientific hands. It was worth the wait, not least for the clues it offers those searching for the enigmatic Ancestor X – the species that gave rise to humanity.

For as long as researchers have been finding ancient human-like fossils, one question has been nagging away in the back of their minds: how are we related to other prehistoric groups and species? In particular, how do we fit in with the Neanderthals and Denisovans who shared Earth with us for most of our existence? It is this question that the discovery of Ancestor X promises to answer. However, the hunt for it has been fiendish, with major twists and turns along the way. In recent years, it has also led to some surprising discoveries, including the revelation that we had misunderstood the way our species, *Homo sapiens*, evolved. Now, with the re-emergence of the Harbin skull, the search for Ancestor X looks set to get easier in some ways – and a lot more difficult in others.

When it comes to the big picture of human evolution, universal consensus is hard to find. However, by the final decades of the 20th century, many researchers accepted a few key points. The first was that all living people today are so genetically similar to one another that *H. sapiens* must have emerged no more than a few hundred thousand years ago. The second was that this happened in a corner of Africa, which would explain why most of the genetic diversity that exists in our species today is largely concentrated in Africa. A third widely held idea was that our parent species also gave rise to a second species, *Homo neanderthalensis*, the Neanderthals. In other words, the two species share a common ancestor, dubbed Ancestor X.

Putting all the pieces together, a relatively simple picture emerged. Several hundred thousand years ago, our parent species was present in parts of Africa and Europe. Then, a small population of this Ancestor X became isolated in Africa for long enough to evolve new genetic and physical traits and give rise to our species. At roughly the same time, another small population of Ancestor X became isolated in Europe and evolved into the Neanderthals. Eventually, the isolation ended. *H. sapiens* and Neanderthals both began to spread, consigning all remaining populations of Ancestor X to extinction. Ultimately, *H. sapiens* spread so far and wide that it encountered Neanderthals – and sent them to extinction too.

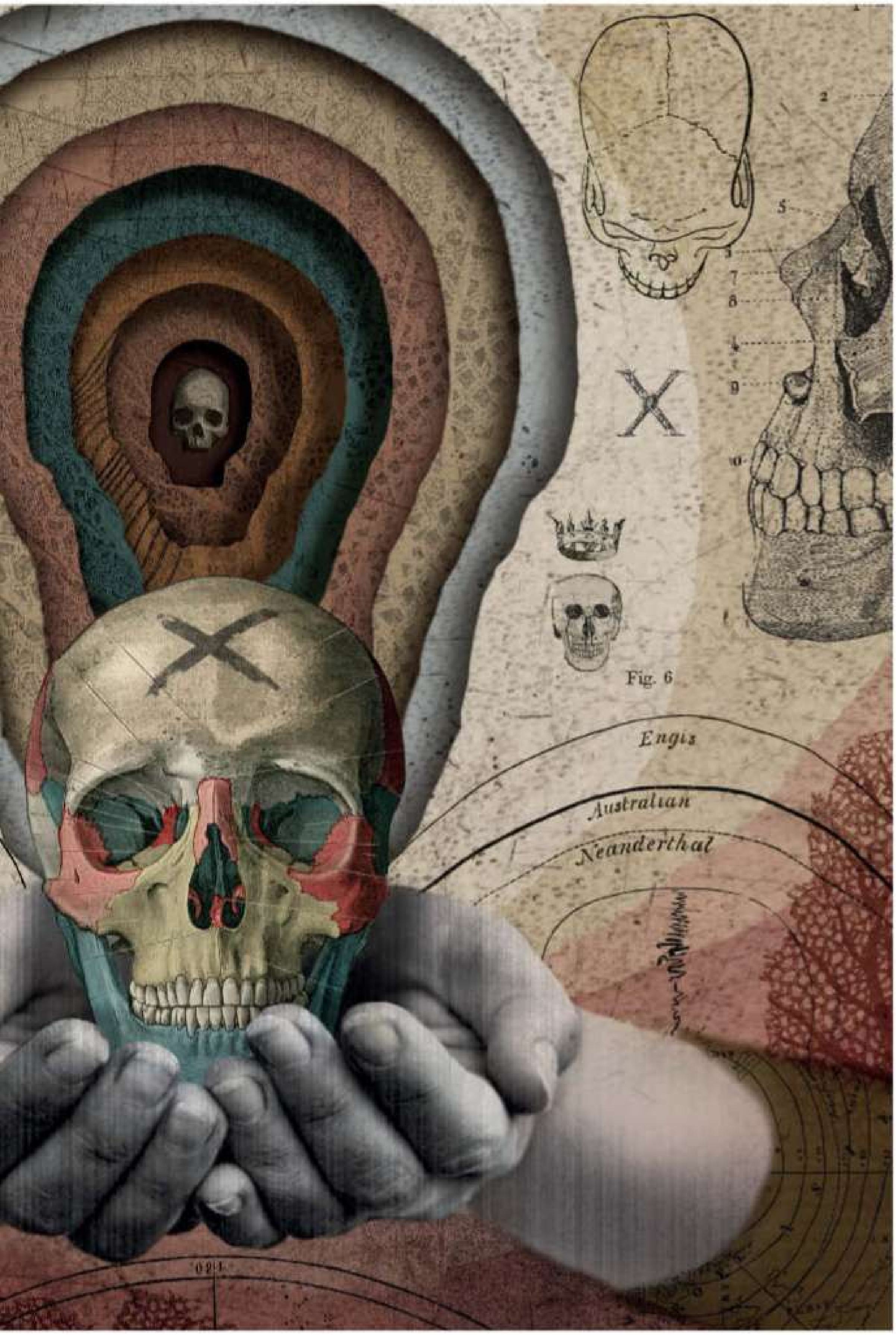
With this picture in place, the search for Ancestor X was on. By the early 1980s, Chris Stringer at the Natural History Museum in London thought he had found it. He had spent years scrutinising the shape of Neanderthal and *H. sapiens* skulls to work out what they had in common: features they had probably inherited from Ancestor X. Both had large brains, similarly shaped temporal bones – pieces of the skull on each side of the head that house the ears – and other features. And, bingo, these were also seen in a third hominin, *Homo heidelbergensis*. What's more, *H. heidelbergensis* had been present in parts of Africa and Europe between about 300,000 and 500,000 years ago. "I thought: well there you are," says Stringer. "It's in the right place at the right time to be the common ancestor."

Too youthful

But in the 2010s, he and many other researchers had second thoughts. Some of the best evidence about *H. heidelbergensis* had come from fossils found at Sima de los Huesos in Spain, and by the mid 2010s, it was clear that they actually looked more like proto-Neanderthals. An analysis of ancient DNA published in 2016 lent further weight to the idea that the Sima fossils were early Neanderthals. Furthermore, using this finding together with their age – around 430,000 years old – researchers could refine the estimate for when Ancestor X had walked the planet. This pushed it back to between 550,000 and 765,000 years ago. Today, some think even this is an underestimate. For instance, a 2019 analysis of Neanderthal and *H. sapiens* teeth suggested that Ancestor X was on Earth 800,000 years ago or more. The message was clear: *H. heidelbergensis* was too young to be Ancestor X.

No matter, though, because a new Ancestor X candidate was already waiting in the wings. Curiously, this suspect – *Homo antecessor* – had been discovered at a site just a few hundred metres to the north of Sima de los Huesos. However, it lived about 800,000 to 850,000 years ago, making it a far more likely Ancestor X, at least on the grounds of age.

If *H. antecessor* is Ancestor X, it literally puts a different face on the story of recent human evolution. "*H. antecessor* exhibits the oldest known modern face so far found," says José María Bermúdez de Castro at the Spanish National Research Centre for Human Evolution in Burgos. Its delicate cheekbones and flattened features are similar to those seen in living humans and are unlike the heavily built faces of Neanderthals. Because of this, there is now a surprising hypothesis about Ancestor X: perhaps it looked a little like us. "Our so-called modern face is an ancient face," says Stringer. The Neanderthal face might actually be far more evolved. ›



> "If *H. antecessor* is Ancestor X, it literally puts a different face on the story"

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That being said, Stringer doesn't think *H. antecessor* is Ancestor X itself. In a 2016 analysis in which he considered all we can now infer about our parent species, he concluded that Ancestor X had a face like *H. antecessor* combined with teeth that were more Neanderthal-like, while the part of the skull encasing the brain looked like that of a primitive *H. heidelbergensis* cranium discovered in Ceprano, Italy. Such fossils are presumably out there somewhere, but they have yet to be discovered. The hunt goes on.

Meanwhile, there are still a few researchers betting on *H. heidelbergensis*, including Axel Timmermann at Pusan National University in South Korea and his colleagues, who published their findings earlier this year. They ran a climate model on a supercomputer for six months to reconstruct how temperature and rainfall might have shaped what resources were available to hominins over the past 2 million years. They then combined their results with thousands of fossils and other archaeological evidence to work out where and when six species of humans – including the early *H. sapiens* – could have lived. Among other things, their results suggested that our species evolved from *H. heidelbergensis* in southern Africa as conditions became hotter and more arid.

> **"Our so-called modern face is an ancient face"**

It is a minority view, though. Most researchers now see hints in the fossils that *H. heidelbergensis* was more closely related to the proto-Neanderthals than to our species. That would make it a dead-end side branch of our family tree that has no relevance for understanding the origin of *H. sapiens*. However, a new twist in the story suggests they could be wrong.

The problem is that we appear to have fundamentally misunderstood the way human evolution works. "The idea humans originated from a small region [of Africa] doesn't make much sense," says Lounès Chikhi at the University of Toulouse, France. "It was clear that it was problematic at least 20 years ago." At that time, he and David Goldstein, now at Columbia University Irving Medical Center in New York, wrote a review paper explaining why. The science is complicated – so complicated that it seems many non-geneticists missed the nuance – but Chikhi says the genetic signals in living humans imply that *H. sapiens* emerged as a "metapopulation" spread over a wide geographical area where several "subpopulations" were interconnected by genetic exchange. Each of these subpopulations was characterised by a subtly distinct genetic signature – and potentially a subtly distinct look.

Significantly, the idea fits well with mounting evidence on the ground. Across Africa, there are fossils between about 200,000 and 300,000 years old that look superficially like *H. sapiens*, but that each carry a unique mix of physical features. They appear to be representatives of some of the subpopulations that Chikhi says mixed and interbred to establish our species as a metapopulation. This idea, published in 2018, has come to be known as African multiregionalism, but Chikhi and Stringer – another advocate of the idea – prefer the term pan-African evolution.

This phenomenon may have implications for *H. heidelbergensis*. A fossil skull from Zambia, labelled as *H. heidelbergensis*, has recently been dated and turns out to be just 300,000 years old. This means *H. heidelbergensis* was still in Africa at the time *H. sapiens* was emerging across the continent. And although *H. sapiens* probably traces most of its ancestry to Ancestor X, Stringer says it is possible that one or more *H. heidelbergensis* groups were among the subpopulations that contributed some DNA to our species. To put it another way, even if *H. heidelbergensis* isn't Ancestor X, it might still be among our ancestors.

Dragon Man

Arguably, an even bigger implication of the pan-African evolution model is that it probably applies to the origin of other hominins – including Ancestor X. If so, our immediate ancestor also evolved through the mixing of numerous subpopulations of its own parent species spread over a wide geographical area. But where in the world did that happen?

To address this question, international collaborative work is required, particularly between Western and Asian scientists because,

East-West relations

Our species was long thought to have evolved from a small, heterogeneous population living in a tiny corner of Africa. Evidence countering this idea emerged two decades ago, but is only now being widely recognised (see main story). Sheela Athreya at Texas A&M University suspects that cultural influences may help explain this. "A single 'pure' form evolving and spreading to replace all others? That's colonialism in Europe and that's manifest destiny in the United States," she says.

To be clear, she doesn't mean that all researchers of European ancestry are racist, but that racist cultural ideas may influence their work, if unconsciously. What's more, a few of these same researchers have been quick to criticise their colleagues in Asia and elsewhere of being under the influence of perceived cultural biases, she says. This has discouraged collaboration and made it difficult to work out how the extraordinary fossil finds made in Asia fit into the bigger picture of human evolution.

"The view is that Asian scientists are biased and ethnocentric, that they like the idea of long-standing regional continuity because the alternative is a replacement model that suggests they haven't been in the area for as long," says Athreya. She thinks this view is incorrect, offensive and – above all – counterproductive because it has encouraged some Western researchers to dismiss almost all scientific findings made by human evolution scientists in Asia. Fortunately, attitudes are changing.

PVE/ALAMY

From left, clockwise: The skulls of *Homo antecessor* and *Homo heidelbergensis;* the oldest known skull of *Homo sapiens*

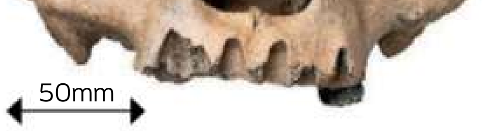
AGEFOTOSTOCK/ALAMY

in recent decades, it has become increasingly clear that Asia is another hotbed of human evolution. Unfortunately, that hasn't always been forthcoming. "For a long time, a few researchers had this attitude: we don't really trust Asian science, we don't even trust the dates on their fossils," says Mirjana Roksandic at the University of Winnipeg, Canada. Whatever the causes (see "East-West relations", left), she thinks the situation is finally beginning to change. "Thankfully, there is now more respect, and more of a push for international collaborations that lead to new ideas," she says.

Which brings us back to the Harbin skull. It was clear from the moment it came to light that it was a significant find, particularly since, like *H. antecessor*, it had a face strikingly similar to our own. Last year, Xijun Ni at the Chinese Academy of Sciences and his colleagues, including Stringer, published a first analysis of the fossil, which is at least 146,000 years old. In particular, they wanted to work out where it sits in our evolutionary tree. Surprisingly, the study suggested the Harbin skull – and a few other fossils, many of them unearthed in China – belong to a previously unrecognised ancient human population that is evolutionarily even closer to *H. sapiens* than the Neanderthals. In an accompanying paper, Ni and some of his colleagues identified it as a new species: *Homo longi*. Stringer isn't a fan of the name because it supersedes one already given to similar fossils, but he doesn't mind referring to the new human by its informal nickname: Dragon Man.

This could prove significant for those still seeking Ancestor X. Although analysis of the Harbin skull is ongoing, Stringer speculates that Dragon Man might have emerged from Ancestor X at around the same time *H. sapiens* and Neanderthals did, implying that our species is one of triplets, not one of twins.

The Harbin skull may be from a sister species to humans and Neanderthals



TOP: MARKUS SCHIEDER/ALAMY; RIGHT: XIJUN NI/CHINESE ACADEMY OF SCIENCES

Perhaps, he adds, this third human group will turn out to contain the mysterious Denisovans, discovered in 2010 and considered a sort of Asian sister group to Neanderthals. Discovering the ways in which these sibling species are similar to or different from our own may offer key insights into our evolution. Even if we accept our species evolved in Africa, "east Asia is an important region for studying the origin of *H. sapiens*", says Ni.

These developments are a mixed blessing. On the one hand, fossils like Harbin could help further refine our ideas about Ancestor X's physical appearance, which might make our elusive parent species easier to recognise when we eventually find it. But on the flip side, Harbin-like fossils imply that the search might be harder than we thought, because Ancestor X could have lived almost anywhere within a truly vast geographical region. "It could have been in Africa," says Stringer. "But it could have been in Europe – that's where *H. antecessor* is – or it could have been in west Asia. It could even have been in east Asia. We just don't know yet." ▮

Colin Barras is a features editor at *New Scientist*

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The science of cooking

From sour to sweet

"Miracle berries" don't taste sugary themselves, but if you eat sour food afterwards, it will taste miraculously sweet, finds **Sam Wong**

Sam Wong is assistant news editor and self-appointed chief gourmand at *New Scientist*. Follow him @samwong1

What you need

Miracle berries
A selection of sour foods, such as lemons, pickles and yogurt

The science of cooking appears every four weeks

Next week

Stargazing at home

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MOST people find sugar hard to resist, and with good reason. Our big brains need lots of energy and sugary foods provide plenty of it. But when calories are too readily available, it is easy to overdo it.

There has been no shortage of research on sugar substitutes that trigger a sweet sensation without the calories, such as aspartame and sucralose, but these compounds also taste slightly bitter for many people. What's more, evidence from animal and human studies has linked some to glucose intolerance and weight gain.

One promising alternative is found in the fruit of *Synsepalum dulcificum* (pictured), a plant native to West Africa. These so-called miracle berries don't taste sugary themselves, but if you try something sour afterwards, it will taste miraculously sweet.

In Benin, where it is known as the sisrè berry, the fruit is eaten fresh and is mostly used as a sweetener to have with sour foods and drinks, says Dèdéou Tchokponhoué at the University of Abomey-Calavi in Benin. "The berry is very appreciated by local consumers, especially the kids and people with diabetes who use it as a substitute for synthetic sugar."

The chemical responsible, a protein named miraculin, was identified in 1968 and a team at the University of Tokyo discovered how it works in 2011. At neutral pH, miraculin is an antagonist to our sweet taste receptors, meaning it blocks the taste of sweetness. But in the presence of an acid, miraculin changes shape and is able to activate the receptors.

Despite the miracle berry's promise as a sugar substitute, it is only produced on a smallish scale and isn't available worldwide. The berries don't travel well and the plant is slow to grow and mature.

To create an alternative source of miraculin, researchers at the University of Tsukuba in Japan have genetically engineered tomatoes to produce the protein, but this isn't necessary, says Tchokponhoué. His team is working on agronomic practices and breeding to help scale up production of miracle berries in West Africa. Earlier this year, a team at Hainan University in China published the genome of *S. dulcificum*, which may help.

Spanish start-up Baïa Food has plans to promote sustainable cultivation of the plant in Ghana and market the dried berries as a food supplement. Last year, the European Food Safety Authority reviewed the safety of dried miracle berries and found them safe to use in food supplements at levels of up to 0.7 grams per day, for adults who aren't pregnant or lactacting.

You can order tablets of freeze-dried miracle berries online, but they are pricey, costing around £18 for a pack of 10. If you can afford it, the berry's taste-twisting power is fun to try at home. Let the tablet dissolve on your tongue, then try tasting acidic foods such as lemons. The effect should last between 15 minutes and 1 hour. ▮

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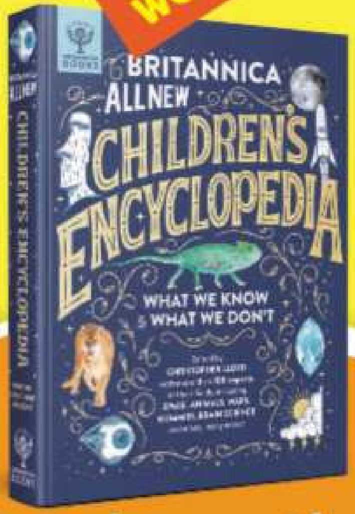

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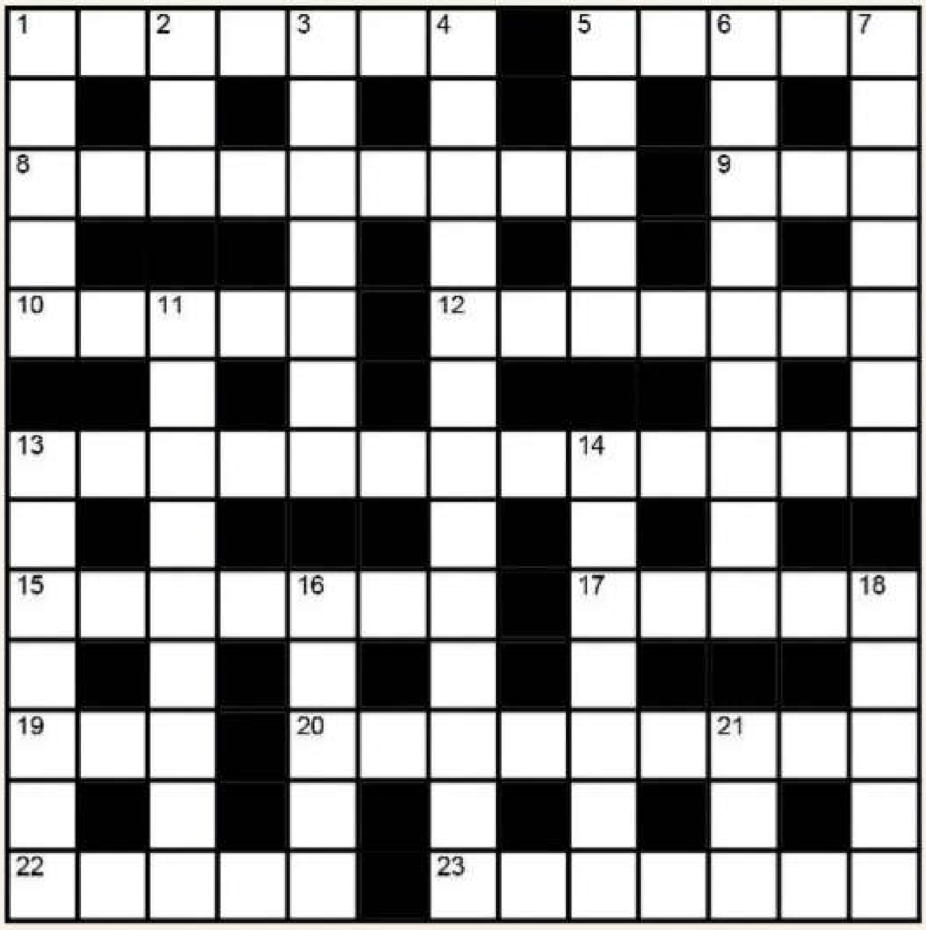
Cryptic crossword #91 *Set by Wingding*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 At sea, easterly wind captured by photograph briefly (7)
5 Disorganised person loses new climbing equipment (5)
8 Bird from South Africa making beer (9)
9 Oxygen absorbed by 60 salmon (3)
10 Reference book finally shortened (5)
12 Chinese army in eastern region shows failure to develop normally (7)
13 Scientist who recently departed calls move "joke" that's out of order (5,8)
15 Astronomer is good boxer, "The Lion" (7)
17 Organs perished next to metal (5)
19 Record mathematical function (3)
20 Concealing oneself in camel skin and donkey tail, as a critic would speak? (9)
22 A little terrier ate larger carnivore (5)
23 Tesla boss dismissing top bird (7)

DOWN

1 Repast always includes something starchy (5)
2 Research group's dog (3)
3 Gopher's coat facilitates and lubricates (7)
4 Decipher it, most logical scientist! (13)
5 Knocked over beer fit for a king (5)
6 Before leaving, Europeans eat what's left (6,3)
7 Nine pennies in bag, part of an athletic physique (3-4)
11 Attention: fruit with reduced calories (9)
13 You heard gibbon lifting container or vessel (7)
14 Feeling electric transport (7)
16 Processed coal left in a restricted area (5)
18 Surprisingly early stratum (5)
21 Joke that would shut someone up? (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #167

1 What is thought to be the largest known supercluster in the universe?

2 A bony external plate found on the skin of crocodilians and certain other animals is known as what?

3 James Cronin and Val Fitch won the 1980 Nobel prize for physics for discovering which phenomenon?

4 A heart rate that exceeds the normal is known as what?

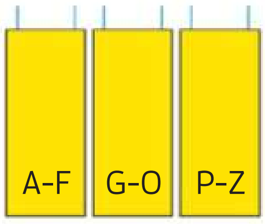
5 Indigobirds, whydahs and cuckoo-finches make up which bird family?

Answers on page 55

Puzzle

set by Zoe Mensch

#183 Animal rights



Hattie keeps an old animal encyclopaedia on her shelf that comes in three volumes, each roughly 5 centimetres thick. The first volume has all the animals arranged alphabetically from A to F, the second from G to O and the third from P to Z.

Hattie has bookmarked six of her favourite animals: the aardvark, fruit bat, gecko, oyster, pangolin and zonkey, with the bookmarks sticking out of the top of the volumes as shown above. At least, that is how they looked until her granddaughter shuffled the order of the books. Now, the bookmarks between the aardvark and gecko are further apart than the ones between the fruit bat and pangolin, but not as far apart as the zonkey and oyster bookmarks.

As Hattie looks at the books on the shelf, the oyster bookmark is still to the right of the aardvark. "Impossible," you say? Not at all. In what order are the books now arranged?

Solution next week

Pipe line

Aiming a hosepipe, intuition told me a 45-degree angle would maximise the distance travelled by the water, as it would for a projectile. But when I did this, the water actually went a shorter distance. Why?

Graham Smith
Melbourne, Victoria, Australia
Isaac Newton used calculus to prove that, in the absence of air resistance, a fired cannonball travels in a symmetrical arch shape, or parabolic path, and he showed that maximum range is achieved by launching the ball at a 45-degree angle. As a cannonball has a very high momentum and experiences a relatively low air resistance, artillery crews have used this principle for 300 years.

But for water coming from a hosepipe, the atmosphere can't be ignored because the stream of water quickly breaks up into droplets that encounter higher levels of air resistance relative to their momentum, compared with a cannonball. This slows the droplets down quickly. What's more, water droplets at the front generate turbulence that affects the paths of droplets behind them.

> "Water droplets from a hosepipe endure high air resistance relative to their momentum, which slows them down quickly"

A hosepipe should therefore be held at an angle of less than 45 degrees to allow the water to cover as much horizontal distance as possible before the velocity of the water is too degraded.

This is evident during water fights with my grandchildren, where I can achieve maximum water-spraying range when I hold the hosepipe at an angle of about 20 degrees. When they are hiding behind a fence, I am able to hit them with a near-vertical stream of water if I hold the hosepipe at a 60-degree angle.

THOMAS COEX/AFP VIA GETTY IMAGES

Where has the water missing from rivers and reservoirs in Europe and China gone?

This week's new questions

Water fall **Where is the water that Europe and China are missing from rivers, reservoirs and underground this year? It must be somewhere.** ***John Packham**, London, UK*

Taste test **Do fizzy drinks really taste different from cans or plastic/glass bottles? My friend prefers cans, but I can't taste any difference.** ***Siobhan O'Shea**, Chelmsford, Essex, UK*

Richard Swifte
Darmstadt, Germany
School pupils learn in their physics classes that launching a projectile at a 45-degree angle maximises the horizontal distance travelled by the propelled object, according to equations of motion. But this ignores an importance factor: air resistance.

Taking drag into account vastly complicates the calculations, since the distance travelled by an object now depends on other variables, such as the direction and strength of the wind, as well as the weight and shape of the projectile.

While ammunition from a tank is aerodynamic and should be fired at an angle of about 42 degrees to achieve maximum range, the optimal angle would be less for increasingly light objects, such as the jet or spray of water from a hosepipe.

Breathe out

We hear about the overload of carbon dioxide in the atmosphere, but what percentage of this comes from human exhalation?

Nick Canning
Londonderry, UK
If we roughly estimate that an average person exhales about 0.66 kilograms of CO_2 in a day, this means that a world population of about 7 billion people will exhale around 1.7 gigatons of CO_2 into the atmosphere each year.

Meanwhile, the estimated total CO_2 emissions per year from global fossil fuel usage in 2019 was about 40.5 gigatons. This means human exhalations produce about 4 per cent of the amount of CO_2 that is emitted by burning fossil fuels.

Most of the problems with excessive carbon emissions result from powering society through our massive use of fossil fuels, rather than the worldwide exhalations that power our own bodies.

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Keith Ross
Villembits, France
The carbon dioxide we breathe out is used by plants to grow through photosynthesis, as part of the carbon cycle. Therefore, it doesn't matter how much CO_2 we breathe out. We are adding to the CO_2 in the atmosphere when we dig up and burn fossil fuels.

***@miclagioia** via Twitter*
Human exhalation is part of the natural cycle of gases entering and leaving the atmosphere, so it doesn't produce any overload per se. But we do contribute via our diets, as food production causes about a third of carbon emissions.

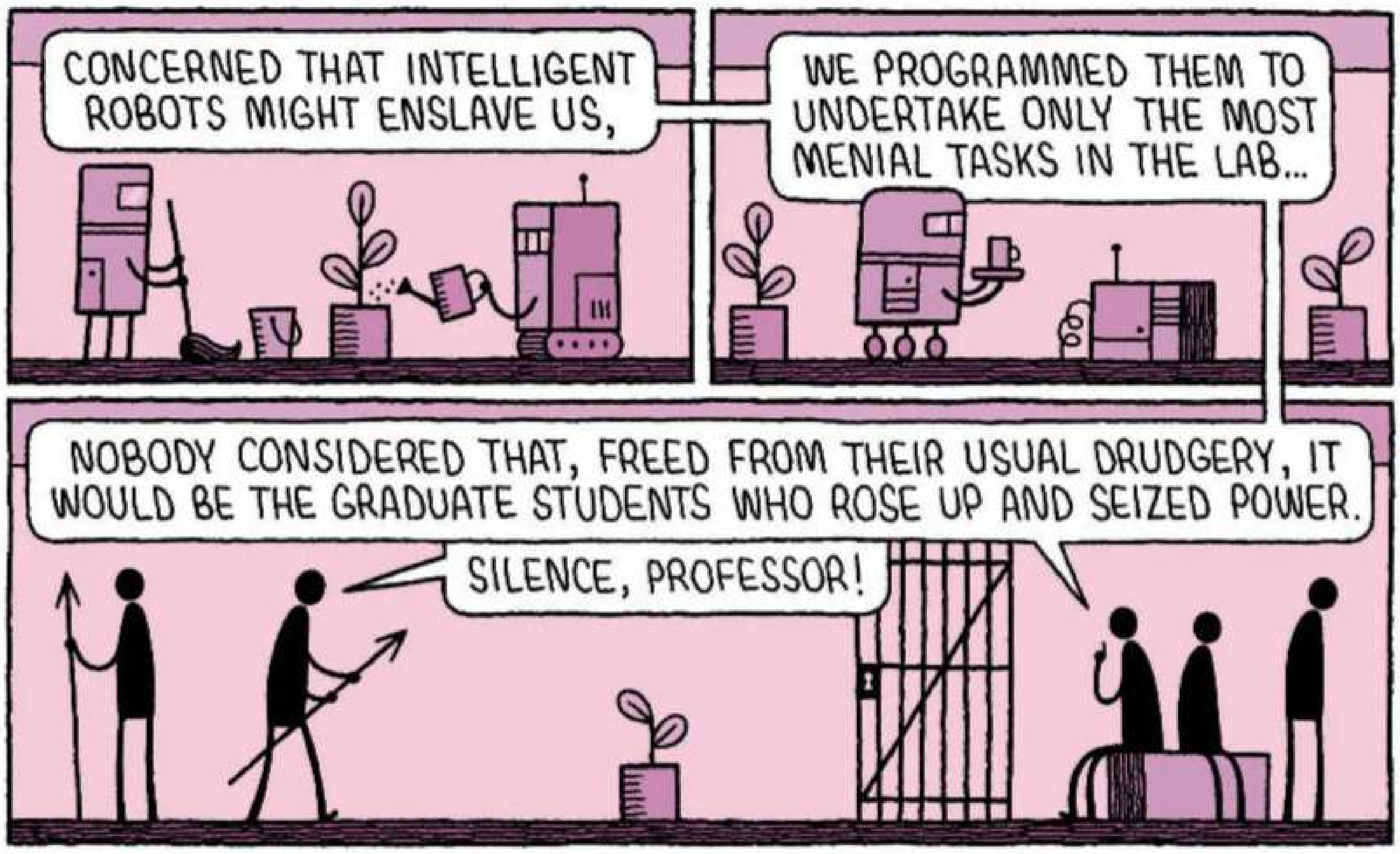
***@krishna97318875** via Twitter*
As much as possible, humans shouldn't exhale, or they can attach a carbon solidifier to their nose and clean their nose every hour or so to protect the environment.

Hiccup cure

Holding your breath while pinching your nose is supposed to stop hiccups, but does anything actually cure hiccups? (continued)

Richard Hind
York, UK
What I find most effective is controlling the breath using what I call "golden ratio breathing". It is a form of breathing for relaxation in which you inhale for a count of five and exhale for a count of eight. You may hiccup once or twice as

Tom Gauld
for New Scientist


CONCERNED THAT INTELLIGENT ROBOTS MIGHT ENSLAVE US,
WE PROGRAMMED THEM TO UNDERTAKE ONLY THE MOST MENIAL TASKS IN THE LAB...
NOBODY CONSIDERED THAT, FREED FROM THEIR USUAL DRUDGERY, IT WOULD BE THE GRADUATE STUDENTS WHO ROSE UP AND SEIZED POWER.
SILENCE, PROFESSOR!

you start, but after half a dozen or so cycles, the hiccups melt away.

Nuala Lonie
Linlithgow, West Lothian, UK
The virtually infallible cure for hiccups is to try to hiccup. My friend has deployed this approach in his work as a teacher. He offered the afflicted child whatever coin came to hand from his trouser pocket if they could produce a hiccup in exchange.

On one occasion, discovering he had offered half a crown, which was a considerable sum back then, he decided to stick with the method and, fortunately for him, it still worked.

William Fairholm
Hamilton, Ontario, Canada
An article I read years ago presented a magic word that would cure hiccups. I can't recall the word, which was long and hard to pronounce, but the idea that a word can cure hiccups stuck in my mind. I figured that it must be the belief that a word can do this that is responsible for the effect.

> **"To prevent hiccups in the first place, the answer is to stay clear of pretty much anything that makes life worth living"**

Ever since, I have used sheer belief to cure my hiccups. In other words, my mind believes hiccups don't matter and so they go away. My sister also successfully used this method for a while, but she lost faith and it stopped working.

Brian Horton
West Launceston, Tasmania, Australia
You can cure hiccups by inhaling increasing levels of CO_2. This can be achieved by breathing into a paper bag, but this treatment should only be done under medical supervision.

Scientists studied this by enclosing people's heads inside large plastic bags. They found that very persistent hiccups stopped when the levels of CO_2 in the inspired air matched that in the expired air. Filling the bag with oxygen made no difference, suggesting it wasn't a shortage of oxygen that stopped the hiccups. The method also didn't work when a hole was made in the bag, indicating that the increased level of inhaled CO_2 cured the hiccups.

Crispin Oates
Whiteley Bay, Tyne and Wear, UK
Except in one instance, my mother's remedy of a teaspoon of sugar has always worked. The one exception was when I took ibuprofen on an empty stomach. This irritated my stomach lining and resulted in me having violent hiccups that lasted for a week!

Andrew McKenna
Queensland, Australia
If you want to know how to prevent hiccups occurring in the first place, the answer is to avoid things like alcohol, eating too quickly and consuming spicy food.

Basically, stay clear of pretty much anything that makes life worth living. ▮

Answers

Quick quiz #167
Answers

1 The Hercules-Corona Borealis Great Wall, also known as the Great Wall, which is about 10 billion light years long

2 A scute, or scutum

3 CP violation

4 Tachycardia

5 Viduidae

Quick crossword #115 *Answers*

ACROSS 8 Lens, **9** Oncologist, **10** Frisch, **11** Neutrino, **12** Ectoderm, **14** Orchid, **16** Etna, **17** Pinna, **18** Last, **19** Kakapo, **21** Aardwolf, **23** Creosote, **26** Breath, **27** Omnivorous, **28** Clot

DOWN 1 Terra cotta, **2** Isospora, **3** Towhee, **4** Scan, **5** Glaucoma, **6** Agaric, **7** USAN, **13** Manga, **15** Insulation, **17** Protocol, **18** Lawrence, **20** Atomic, **22** Ribose, **24** Ramp, **25** Enol

#182 Riff raffle
Solution

Each strip contained the same number of tickets. Palindromic numbers are of the form ABBA, and if you experiment with a few such numbers (e.g. 1661, 8228 and 5775), you will find they are always divisible by 11.

This is because ABBA in longhand is 1000A + 100B + 10B + A, which can be simplified to 1001A + 110B, which equals 11 × (91A + 10B). Since 1001 is itself a multiple of 11, the tickets must have been sold in strips of 11, with the winning tickets always being the first one in the strip.

Trust the map

Bringing Ethel, our capuchin monkey friend, along for the ride turned out to be a mistake. For one thing, she insisted on navigating. "Are you sure this map is up to date?"

"Ptolemy was the finest of Roman cartographers," we snapped, "and if he placed the Welsh coastline 13 kilometres further into the sea than it's currently rumoured to be, that's good enough for us."

Feedback stabbed at the latest issue of *Atlantic Geoscience*, which reports the existence of two lost islands in Cardigan Bay, identified by Simon Haslett at Swansea University and David Willis at the University of Oxford through folkloric accounts, field studies, geological surveys and – the clincher – a medieval map. "Legend has it that the bells of the lost kingdom of Cantre'r Gwaelod can still be heard on quiet evenings!"

"You do know, don't you," said Ethel, carefully, "there is a difference between present and past? And that there's such a thing as erosion?"

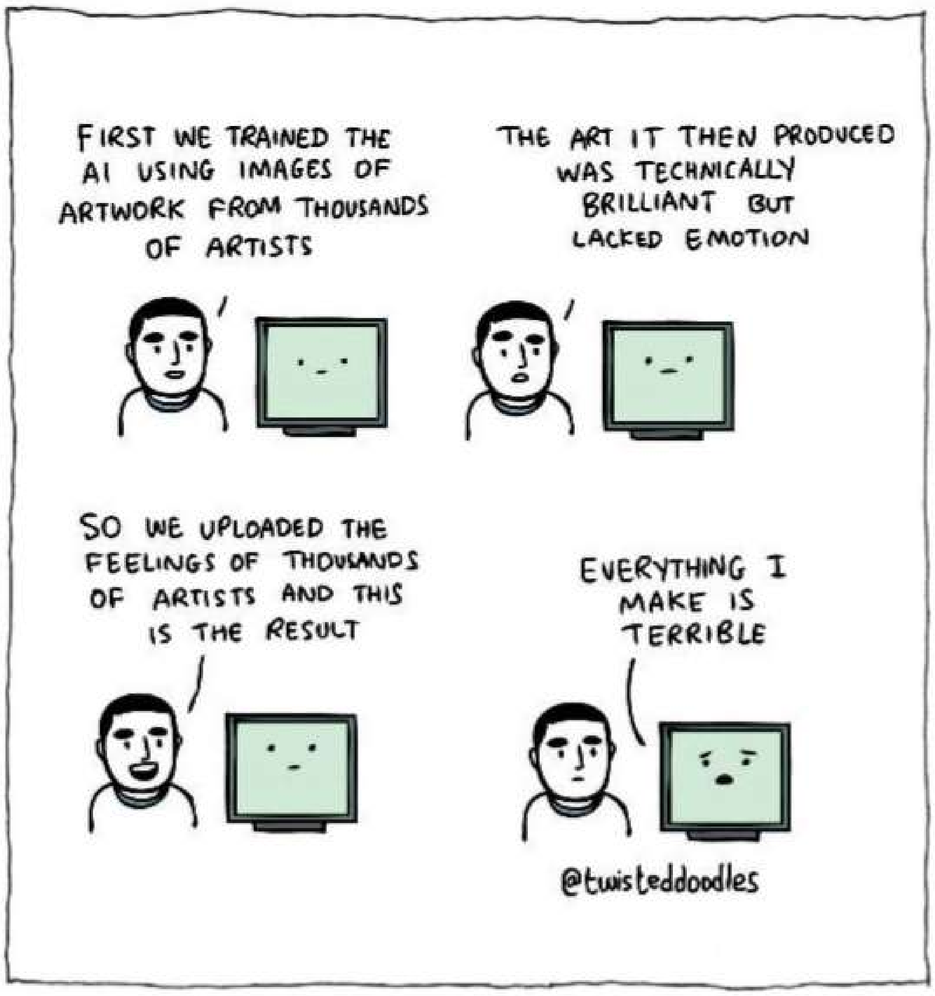
Meta miracle

We scoffed at this primate's primitive conceptions. "We live in an age liberated from linear time! Consider how Mark Zuckerberg, the Moses of metaversal reality, has recently appeared to the world embodied as an 18th-century infant Jesus."

Arix King, a product designer at Riot Games, was on a date with his girlfriend at the Los Angeles County Museum of Art when the CEO of Meta appeared to him in the form of a 300-year-old plaster sculpture from Peru. The photographic evidence Vice.com brings to this tale is impressive: the Virgin in the *Virgin of Mercy, or "Pilgrim of Quito"* is quite clearly holding, in place of the Saviour, a diminutive Zuckerberg.

Ilona Katzew, the curator, anatomised the figure's "smooth and youthful features, rosy cheeks, lifelike eyes made of glass, pursed red lips, and plump, shiny flesh..."

Twisteddoodles *for New Scientist*


FIRST WE TRAINED THE AI USING IMAGES OF ARTWORK FROM THOUSANDS OF ARTISTS
THE ART IT THEN PRODUCED WAS TECHNICALLY BRILLIANT BUT LACKED EMOTION
SO WE UPLOADED THE FEELINGS OF THOUSANDS OF ARTISTS AND THIS IS THE RESULT
EVERYTHING I MAKE IS TERRIBLE
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com or New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT

Consideration of items sent in the post will be delayed

"I wonder what she thought of the statue?" "Funny," Ethel grumbled, crumpling the ancient map in her paws.

Sound judgement

"Look, I'm trying to sleep, do you mind not making those vroom-vroom noises the whole time?"

"But Ethel, we're in an electric car! We need vroom-vroom noises!" Why else, we explained to her, with a saint-like patience, would Dodge have built the Charger Daytona?

This electric vehicle comes complete with exhaust pipes that make noise and a transmission that, quite without need or reason, shifts gears. CNN reports that, in an effort to reassure a clientele wedded to the muscle-car aesthetic, it has been equipped with various exhaust pipes that generate up to 126 decibels of vroom.

"Alas, we have to wait till 2024 to be able to buy this excellent vehicle, so until then – VRRRRR..."

"That's it!" Ethel cried. "I'm phoning the cops."

Call of nature

If only she followed IFLScience, she would have known that this call wouldn't end well.

On 13 August, San Luis Obispo County Sheriff's Office received a silent, abruptly truncated 911 call from a California zoo. There was, it transpired, no emergency, but assistant director Lisa Jackson had recently lost her phone while riding a golf cart through the zoo with a 10-month-old capuchin monkey called Route. Route, playing with this new toy some hours later, seems to have hit upon a lucky button combination.

Ethel was scandalised. "I'm no phone thief!" she cried. But the Welsh constabulary were having a quiet day, and soon blue lights appeared in our rear-view mirror.

We pulled over. Ethel flung open the door and, screaming various imprecations, scampered away over the Brecon Beacons, pursued by law enforcement. Feedback noted, with irritation, that she still had our map. How selfish!

Wrong side of the bed

But this is the sort of behaviour you can expect from the sleep-deprived. The Science Daily website currently features a study led by Eti Ben Simon and Matthew Walker at the University of California, Berkeley, which shows that sleep deprivation makes people less willing to help others. Charitable giving drops 10 per cent after the beginning of daylight saving time. Walker goes so far as to assert that sleeplessness "degrades the very fabric of human society itself". Reflecting thereon, Feedback opted for a little doze.

Moonraker

Up among the hills, we contemplated a sliver of daytime moon and wondered (as one does) if Earth could sustain more than one such satellite. A recent study in *Monthly Notices of the Royal Astronomical Society* reckons Earth provides stable orbits for two more moons like ours, four Pluto-mass moons and seven moons the mass of Ceres.

A thought experiment, of course – but we couldn't help but wonder, as we dozed off, why our sky was so empty. Where might these extra moons of ours have ended up? Did they fall to Earth in ancient times, like that second dinosaur-killing asteroid, whose impact crater has been discovered off the coast of Guinea, it was reported last month? And if they did, where might they be buried?

We shut our eyes, bathing in the evening hush, and far to the west, from deep under the waters of Cardigan Bay, came a gentle peal of bells. ▮

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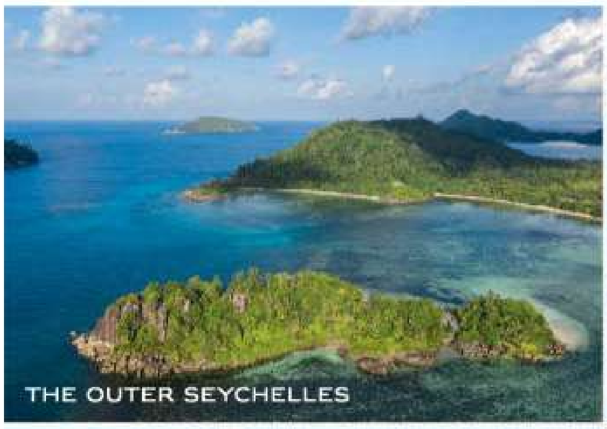
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SEA LION,
GALAPAGOS,
ECUADOR

ON OUR WATCH

Hope can now be spotted across all our planet's seas and oceans. Sites are made into aquatic havens by local communities, to safeguard the richness and diversity of the ecosystems they depend on. Sylvia Earle's invaluable experience as an explorer and marine biologist continues to help further their goal, through her organisation, Mission Blue. Together, they have created over 130 Hope Spots and counting. Carrying a message of hope for generations to come. It is that vision, that dedication to a perpetual planet, which we are proud to stand by. **For as long as it is needed.**

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